AD NUMBER
AD250002
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited. Document partially illegible.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; JUN 1960. Other requests shall be referred to Army Ordnance Tank Automotive Command, Warren, MI 48090. Document partially illegible.**
AUTHORITY
USATAC ltr, 24 Oct 1969

61-2-1 XEROX

302 100

ENGINEERING SUPERVISION COMPANY

CONSULTING AND MANAGEMENT ENGINEERS

ENGINEERING STUDY AND REPORT
on
DIE FORGING OF TANK HULL FRONTS AND TURRET COMPONENTS

Respectfully submitted

by

ENGINEERING SUPERVISION COMPANY
51 East 42 Street
New York 17, N. Y.

J-139
6:60

INDEX

INDEX (contd)

INDEX (contd)

INDEX (contd)

INDEX (contd)

SECTION I

STATEMENT OF WORK; CONCLUSIONS AND RECOMMENDATIONS

I - Preliminary Remarks

This report is organized in several sections.

Section I covers general matters, like scope of work, conclusions and recommendations, etc.

Section II contains the discussion of the forging process.

Section III presents the analysis of the suggested manufacturing method for various portions of the hull and also discusses the manufacturing of the turret.

Section IV covers the industrial engineering of the recommended process, plant layouts and operational sequences.

Section V contains the budgetary estimates of first cost, annual operating cost and total conversion cost.

Section VI presents the evaluation of the industrial engineering study and submits recommendations regarding prototypes.

Section VII contains exhibits and drawings.

II - ACKNOWLEDGEMENTS

This report was sponsored by the Industrial Engineering Branch, Industrial Division, Detroit Arsenal, Ordnance Tank Automotive Command, United States Army, Centerline, Michigan.
(Contract No. DA-20-089-ORD-38738)

The staff of the Engineering Supervision Company expresses its appreciation for understanding and helpful assistance, advice, cooperation and suggestions to all participating persons and organizations, in particular to:

Mr. Avery Fisher, Project Engineer, OTAC

Research Division, College of Engineering,
New York University

Blaw Knox Corporation

Lukenweld Corporation

Pencoyd Steel & Forge Corporation

Salem-Brosius Company

Wyman-Gordon Company

or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

This report may not be reproduced or published in any form in whole or in part without prior approval of the United States Government.

Information on pages 13.01 to 13.06 inclusive and Exhibits A and B of this report is information proprietary to Engineering Supervision Company, New York, N.Y. The reproduction of these pages and exhibits by any one except the United States Government is subject to prior written approval of the Engineering Supervision Company.

III - STATEMENT OF OBJECTIVE

The M-48 medium tank as well as the main battle tank (T-95, M-60) both have a cast steel hull and cast steel turret. The turret is a single piece casting. The hull is manufactured either as a single piece or a multi-piece casting. The lead time from the decision to reopen a Government owned stand-by casting facility to the moment when cast hulls and turrets begin to leave the facility in quantities is extremely long. The costs of cast hulls and turrets are considerable.

The objective of this study is to explore the feasibility of some other manufacturing method which would offer shorter lead times, maybe lower cost and, possibly, the opportunity for the utilization of the contemplated facility in peace time, thus making good use of the capital investment and eliminating the substantial cost of stand-by maintenance.

IV - SUMMARY OF WORK PERFORMED

Keeping in mind the objective and the Statement of Work included in the order, the following work was performe d:

1. The tank hull, as presently designed, was analyzed.
2. A determination of the best manufacturing method for the hull was made. This method consists of:
   a) manufacturing the center and the rear portions of the hull in sections from plates bent and crimped into shape.
   b) producing the nose as a closed die forging in one piece thus avoiding in the front portions any welds which may be ballistically unacceptable.
   c) welding of individual parts of the hull (plates and the forged nose) into a monolithic structure.

3. The turret was analyzed.

It was determined that while forging of the turret in one piece is feasible, the size of equipment required would exceed the limitations imposed by the present state of art.

It was realized that:

a) the manufacture of turrets out of several forged and welded sections would be of questionable value from the ballistic point of view, considering the exposed welded seams in the turret.

b) the exploration and development, beyond the present state of the art, which would be necessary to make the single piece turret forging feasible would require R & D funds not available at present.

Therefore, the decision was made to reccomend deferring further work on the turret until such time as more progress had been made on the hull.

4. The manufacturing process for the hull was analyzed in detail. Plate bending, plate crimping, and welding being conventional procedures, all attention was concentrated on the closed die forging procedure for the nose.

5. Process flow diagrams were determined.

6. Layouts of four typical plants were developed:

   a) an isolated plant including an ingot casting facility

   b) an isolated plant with ingot supply from elsewhere

   c) a plant adjoining an existing Government owned facility capable of casting the necessary ingots (Armorcast plant in Birdsboro, Pennsylvania).

   d) a plant forming a part of an existing Government owned forging facility (forging plant in North Grafton, Massachusetts, operated by the Wyman-Gordon Company).

7. The permission to make use of an available description of the main (and crucial) piece of equipment (a 75,000 ton closed die forging press of a new compact, low-cost design) was secured. Such description was incorporated into the report*

---

* The press in question was developed by the Engineering Supervision Company for a different, privately financed project. No costs have been incurred and/or charged to the Government in connection with development of this press or in connection with incorporation of the description into this report. Neither has the Government acquired any proprietary rights in connection with the designs or development of this piece of equipment.

8. The first cost of a facility as per Item 6b, were estimated.

9. The annual operating cost of a facility as per Item 6b, were estimated.

10. The conversion cost of the nose manufactured in accordance with the recommended method was estimated.

V - CONCLUSIONS AND RECOMMENDATIONS

1. The new manufacturing method of manufacturing the tank hull (single piece seamless closed die forged nose, other portions fabricated from plate) is feasible and within the present state of art.

2. Also feasible is the forging of a single piece turret; however, this process would exceed the limits of the present state of art and would require a certain amount of additional applied development.

3. The new manufacturing method offers substantial advantages in terms of:

    Lead time

    Technology (metallurgical properties)

    Manufacturing cost

    Utilization of the installation in peace time, and, therefore elimination of stand-by cost

    Disposition of the majority of present casting facilities.

4. It is recommended therefore that the continuation of the project be approved along the following lines:

   a) procurement of prototypes of the forged nose

   b) preparation of completely detailed process and operation sheets for the closed die forging process

   c) study and preparation of a general layout of the special 75,000 ton press, sufficiently detailed to allow the invitation of preliminary manufacturing bids on a competitive basis

   d) preparation of a detailed comparison between the various possible solutions for the forging plant (isolated plant, plant combined with a forge, plant combined with a foundry, etc.).

   e) detailed study of the peace time manufacturing program for the contemplated facility for the purpose of determining the feasibility of keeping the plant active at all times

   f) deferment of any changes in the present manufacturing method for the turret until the nose project has advanced at least beyond the prototype stage.

5. It is recommended that the present contract #DA-20-089-ORD-38738 be extended to cover work outlined in Items 4a-4e and that funds for this purpose be appropriated.

SECTION II

THE FORGING PROCESS

VI - INTRODUCTORY REMARKS

Preliminary discussions of the project with the representatives of the OTAC revealed the following as the main reasons for the desire to explore methods other than casting for the manufacture of hull and turret:

1. Generally speaking, the small quantities of hulls and turrets required in peace times are produced in commercial plants. The large quantities required at the start of and during emergencies cannot be produced in such commercial plants. Therefore, Government owned plants have been built which are maintained in stand-by condition by private contractors. A substantial time lag (so-called "lead time") of many months is inevitable whenever a stand-by casting plant is to be reopened. The required lead time is so long that the entire project becomes problematic even in case of an all out effort. For a limited engagement, the value of reopening a stand-by foundry is practically nil.

2. Apart from the initial time lag, the actual manufacturing lead time of a foundry process is also long:

a) Molding

b) Slow cooling of the poured metal

c) Slow stress relieving and annealing

d) Thorough checking and quality control operations (X-ray, reflectoscoping, magnafluxing, dimensional checking and all metallurgical determinations) are extremely time consuming.

3. The casting process is rather expensive:

   Both elements of cost, the first cost representing the initial investment in the plant with substantial floor space as well as the operating cost, are high.

It is understandable that a search for other manufacturing methods should have been started at an early date.

The fabrication of the hull from plates of proper configuration appears an obvious alternative to casting. However, ballistic considerations forbid the generation of welded seams in some portions of the nose of the hull or in certain exposed parts of the turret. In addition, the variations in the wall thickness within the nose section proper are such that the use of welded plate construction would present an inordinate number of weld seams in the nose or result in a compromise of equalized section thickness which would add substantially to the weight of the vehicle.

Just as plate fabrication seems to be an obvious method for the production of major portions of the hull, so the closed die forging process appeared to the investigators to be a most promising solution of the production problem for the nose portion.

The processing of the nose portion of the hull for the closed die forging method is discussed in great detail in further sections of this report.

As to the forming of the rest of the hull from fabricated plate, it would suffice to say that the shaping and trimming of the plate in required sizes represents a conventional operation. The same goes for reinforcement of areas around the holes in the plate which can be accomplished either by crimping or welding of pads.

It is also an established fact that the total cost of plate fabrication (cutting, shaping, bending, crimping and welding) are substantially lower than the cost of an equivalent casting.

There are several other less conventional methods of plate forming which were reviewed by the writers of this report.

These methods did not seem to offer any additional advantages over conventional plate fabrication and therefore they were discarded. Additional information on the plate forming operation will be found elsewhere in this report.

VII - GENERAL APPROACH TO THE PROBLEM

The engineering study of the detail drawings of the tank hulls and of the tank turrets for the medium tank as well as for the main battle tank, reveals that the possibility of producing one piece forgings of either the tank hull or the tank turret is remote.

From the point of view of pure machine element design, these have been designed to be produced by the casting method, and as such, the conversion of these elements to forgings involves the re-design of the elements. Such a re-design of the basic elements of the tank must consider the capacities and suitabilities of the two processes involved.

In the heretofore used production method, there is essentially no size limitation to the amount of metal required to form any of the tank elements, including nose or turrets. Walls of varying cross section for the hulls or turrets can be provided if appropriate special techniques for transitions between heavy and light sections are applied. The size of the ultimate casting is dictated only by the metal capacity of the pouring ladle and by the size of the pouring trough or pouring floor in the foundry producing the elements. Further, the design of these tank portions for production by castings is characterized by the profusion of holes, undercuts, bosses, pads, etc., all of which can be produced in the casting with the expenditure of a very small amount of effort in terms of time, metal and material.

After many years of endeavor, the American steel foundry industry has reached a high peak of technique and efficiency and is fully capable now of making tremendously complex castings of large sections requiring the pouring of metal in excess of 500,000 pounds per piece.

The closed die forging industry, however, is of a considerable more recent origin, and exhibits a conspicuous lack of proper equipment for the production of sizes under discussion. The requirements for press forming a single piece tank hull approximately 21-1/2 feet long and a maximum width of 9 feet, with sections to be formed in three mutually perpendicular planes, would require completely new press concepts. Therefore, the writers of this report concluded that the manufacturing concept used heretofore must be either modified in accordance with the abilities of the present state of art or this project will be faced with the necessity of long and drawn out research and development programs.

The preliminary design work contained in this report consisted primarily of analyzing in detail those tank elements which are suitable for production by closed die forging within the limitations of the present state of art.

VIII - THE CLOSED DIE FORGING PROCESS

A. Closed Die Forging Process

This section describes the closed die forging process in general and serves as an introduction to a detailed investigation (elsewhere in this report) of the process as applied to the nose portion of the tank hull.

1. Cold and Hot Forming of Metals

Cold forming, as the term suggests, is accomplished at or near room temperature. Forming in the cold state ordinarily results in the improvement of the physical properties of the metal, however, it allows small changes in shape (small reductions) only.

The hot forming of metals may be accomplished by rolling, by hammer or by press forging and by extrusicn. While these are the major methods, other means of hot working involve hot spinning, hot drawing, hot flanging and hot bending, hot rotary swaging and hot roll forming. Some of these methods are particularly suited to the production of certain types of shapes of products;

for example, extrusion and rolling are best to produce long elements of uniform cross sectional area, while other methods produce cup shaped or drawn parts most economically.

2. <u>Hot Forging</u>

The hot forging process for the shaping of metal is one in which plastic deformation of metal may be controllably applied to form and shape the metal to the desired external configurations and simultaneously, to refine the grain size and to orient the grain flow patterns of the metal in order that the mechanical properties be improved.

Forging may be accomplished by repeated blows on the material as is done by a forging hammer, or by the application of a single, slower, squeezing action of a press. Referring to the temperature of the work piece, metals may be forged while they are hot or cold. A material which is at an elevated temperature and is therefore in a plastic or semi-plastic state is more easily formed. Forming in the hot range permits large deformations and severe reductions in area. At the same time, however, the prolonged holding of the material at elevated temperature causes a growth in grain size which adversely affects the physical properties, in particular, the ductility.

3. Closed Die Forging

Closed die press forging refers to the shaping of the metal with a single squeezing action, causing the heated, plastic material to be forced into the convolutions of an enclosing matrix.

The forging process is frequently used to break down the primary structure of cast ingots. It is also used for the preparation of the ingot for further handling by other forming means. Finally, it is also used for finishing operations in the productions of various end items. Such parts as axles, gear blanks, wheels, are produced with flat (or "open") dies. This type of forging makes little effort to accurately size the material other than to roughly prepare the parts for final reduction to shape and size on a machine tool, or in some other chip forming operation.

Since the production of closed die forgings is accomplished by the relative motion of the die halves, the process is one in which the metallurgical refinement and mechanical property improvement will be obtained simultaneously with the contour forming. As a result of this, much work has been done in the last decade to determine the effect of the rate of deformation on mechanical structure and physical properties. In the same period much effort has been devoted to the design of production means to accomplish the plastic forming of metals according to the desired deformation rate pattern.

4. Hammers and Presses

Equipment for the production of forgings is frequently classified as hammers or as presses. In either method, the metal is shaped between a pair of dies. In one instance, one die member remains stationary, attached to the fixed member of the forging instrument while the second is permitted to exert pressure by moving in on the material to be forged. In one variety of hammer, both dies move towards each other simultaneously creating pressure on the work piece. With this latter method a greater portion of the energy of the moving hammer parts is absorbed by the work piece than by the conventional arrangement, in which a large part of the work of the moving die is absorbed in massive steel and/or wooden and concrete structures. While hammers of great size have been built, the larger sizes of hammer find little favor among American forging manufacturers. One of the main reasons is that the large amount of energy absorbed by the hammer structure leads invariably to a premature destruction of the hammer itself.

Presses may be either mechanically or hydraulically operated. The mechanical presses, driven by an electric motor through large reduction gears and a flywheel of considerable energy storing capacity, are used for the greatest percentage of forging production. While these machines offer accurate, repetitive, high speed production, the nature of their drive mechanism does not suit them for the production of forgings in deep multi-section dies.

For general purpose work requiring long forging strokes of high capacity or repeated operations on different sections of a large forging, the hydraulic forging press is the best suited machine.

The forming forces are developed by the press as required by the process and no large amount of kinetic energy is stored and suddenly released as in the hammer. Long strokes of a hydraulic press allow the following through with continuously applied pressure instead of sudden impacting by means of a blow. Since the energy is transferred during the entire stroke, the total work performed by a hydraulic press is substantially larger than that produced by a hammer.*

---

* One must realize, of course, that, because of the relation between stroke and work, very thin pieces are not well suited for press work. In such cases, the instantaneous release of energy by the hammer is more effective.

5. Large Forging Presses

Large presses for the production of closed die forgings such as are required for the manufacture of tank hull (and turret) components are complicated and specialized machines, of high specific pressure capacities, a variety of operating speeds, speed controlling and speed indicating means, shifting tables and tool changing devices, and ejection mechanism. The modern closed die forging press is provided with many means to improve the rate at which production can be accomplished. In addition to refinements in press control and speed variations, equipment has been devised to permit ready insertion and removal of dies, work pieces, and finished products.

The amount of effort required to produce certain enclosed shapes is a function of the material forged, the temperature of forging, the rate of deformation and the configuration of the die members. The design of dies for the production of forging must consider the shape to be provided, the temperature of the metal being formed and the location in the die of the center of the forming force. Since all presses now in use are subject to the deleterious effects of the application of eccentric loads it is incumbent on the die designer to provide an arrangement which will contain the center of pressure of the shape to be produced within a small area around the forging axis of the press.

6. Application of Closed Die Forging to Tanks

It is proposed that the production of tank elements be accomplished by forging, modified in its last stages by reverse extrusion, that is, by the direct application of the force of a punch upon material enclosed in a die. During the initial stages the material will be caused to flow plastically into the die and to fill the crevices in the nose thereof; during the latter portions of the process the preformed material will flow around the punch conforming to the shape of the moving punch and to the shape of the enclosing stationary die.

While the strength of the steel is drastically reduced at temperature of 2,000°F (to maybe as low as 2,000 psi), the actual specific forging pressure (the total amount of forging effort divided by the area transverse to the punch motion) may be ten to twelve times this amount due to the effect of friction between the metal being formed and the forming tools (punch and die). In recent years, lubricants have been devised which serve to insulate the critical die members from the extremely high temperatures of the metal and which simultaneously lubricate the passage of metal into and along the dies, thus reducing the friction.

In addition to a large amount of the forging press effort used to overcome the friction force described above, additional substantial effort is required to overcome the internal resistance of the metal. The effort to overcome this latter force is inherent in the process and cannot be reduced by insulating means.

B. The Metallurgy of the Proposed Process

1. Forging Materials

The history of the production of combat type of armored vehicle has seen the use of a large variety of materials. However, these have all been variations of homogeneous cast steel armor. Except for one experimental effort, no extensive production has been attempted in the fabrication of this type of vehicle from other than cast materials. To our knowledge, no extensive ballistic tests have been performed to determine suitability of other than cast steel components. The production of major tank components, turrets and hulls, as forgings introduces problems in material not heretofore experienced. While the final properties of materials specifications can be prescribed, the nature of the production processes and their effect on the metal must also be considered.

The following table specifies three (3) alloys known to produce armor of appropriate ballistic characteristics:

Alloy	A*	B	C
C........	.32	.32	.32
Mn.......	1.00	.35	.80 - 1.20
Cr........	2.50	1.25 - 1.65	.60 - 1.00
Ni........	-	3.25 - 3.50	.80 - 1.20
Mo.......	.60	.15	.40 - .60
Si.......	-	-	.50 - .80
S.......	.035 max.	.025 max.	.025 max.
P.......	.035 max.	.025 max.	.025 max.

Alloy B shown above is similar to the one known as "Krupp Armor Alloy" which has been in use for many years and is known to be used as rolled or as forged armor. While it is also known that hulls and turrets produced from this alloy would meet the military ballistic specifications, one must also consider the availability of the component alloying materials in a period of national emergency. In this respect we may anticipate difficulties in obtaining sufficient quantities of nickel, which, for this particular alloy, is a major constituent.

The alloys designated as A and as C above are readily processed as forgings (as is alloy B, too). Both have been supplied.

---

*A possible modification of Alloy A would be one with a silicon content of about .75% and carbon reduced to about .25%.

Forging of these materials does not produce difficulties beyond those experienced with other medium carbon steels. In case of an emergency, the metal most easily provided would be that shown under C, the constituents of which are most likely to appear in a large percentage of scrap metal today, or, better yet, scrap that will be available during an emergency situation.

Thus, while we have available the material which can produce hull and turret forgings of suitable characteristics, it is anticipated that additional work will be required to finally ascertain the exact alloy to be used depending on the ballistic characteristics required, the weight ultimately required, and the metallurgical properties resulting from the forging operation (which are expected to exceed the properties of cast material).

Anticipating further discussion elsewhere in this report, it should be stated that due to the amount of hot work involved in the proposed closed die forging process makes it feasible to use cast ingots thus greatly reducing the cost of metal.

2. Physical Properties

The mechanical requirements as described in the military specifications MIL-A-11356 B (ORD) indicate that the alloy selected will require a heat treating operation. It is proposed that the hardening and drawing processes which will follow the closed die forging be separated by a controlled quench. It is expected that sample tests with this sequence will demonstrate that the customary quench after drawing will not be required.

While the hardening and drawing processes are to be accomplished using known methods and available equipment, the quench procedure carried out on components of non-symmetrical design, non-uniform cross-section and irregular shapes is sometimes associated with severe dimensional distortions such as twisting, warping, etc. and by occasional cracking and failure of the piece. It is proposed that the redesigned tank element be substantially symmetrical about the long axis and be of wall thickness as uniform as is commensurate with the ballistic requirements; in this way, the difficulties heretofore associated with quenching from the elevated hardening temperatures will be avoided. Whereas the greatest difficulties in conventional quenching arise from the different cooling rates of the multi-sectioned casting, it is anticipated (based on already available experience) that the application of the quenching fluid (water or oil) at a controlled rate of flow, such rate to be determined best on the relative thickness and heat content of the various cross-sections, will produce excellent results.

Work already done on selective quenching of heavy castings has already indicated that in the case of castings for tank noses most distortions can be eliminated with as few as three (3) controlled volume rate sources. The provision of controlled volume rate sources will serve the following prime purposes:

a) Quenching will be accomplished at a controlled rate of speed for each section depending on the volume of metal to be cooled and therefore, the heat to be removed. The quenching rate will be adjusted to provide a uniform over-all cooling rate.

The quenching operation will be accomplished without the necessity for quenching presses, for clamps or for holding fixtures. The controlled rate of flow of quenching medium will provide predictable, uniform and repetitive results. The distortions ordinarily found in heat treated castings account for a large percentage of rejections during the manufacturing process. Proper procedures can prevent this difficulty in forgings. Therefore, it is proposed that details of the quenching procedure be developed during the manufacture of proposed prototypes so that the forging distortions will be minimized and the rejection rate due to the distortion effect reduced to a minimum.

C. Configurations of Items Required

The provision of hulls and turrets as castings requires that a set of standards known to designers and to foundry men must be adhered to in order to obtain sound, stress free, homogeneous castings. Some of the principles which must be observed are as follows:

Design for casting soundness: avoidance of sharp angles and corners and sudden changes of section.

Bringing the minimum number of sections together at a common point.

Designing of individual sections as nearly uniform as possible.

In accordance with some of these principles, it is possible to produce sound armor sections as castings.

The design for forging of same components, hulls and turrets, must consider several additional factors while placing less emphasis on some of those mentioned above.

In order that a forging be produced in as simple a die as possible, it is desirable that the required piece be designed without undercuts, that is, that the element be composed of sections which fall into wedge type or cone type configurations in an access parallel to or shallowly incident to the access of the pressing direction. In this way, the use of multi-element dies, transverse clamping cylinders and expanding mandrils is avoided. While the use of any of these techniques is known to yield an advantage in the production of certain similar forgings, the adopting of such techniques to the grandiose scale considered herein is not considered practical at this time.

The general tool set up used for the production of the elements in question consists of a tapered or basically conical shape male punch engaging in a similarly shaped socket. The outer form of the piece required is produced by the contour of the female die while the inner contour is produced by the shape of the male die or punch.

It is anticipated that the arrangement of the temperature and flow characteristics in the ultimate forging alloy, suitable die proportions accounting for best dimensional accuracy, inserts for wear points, lubricants to be used, die coolants to be used, etc., will be ascertained during the manufacture of proposed prototypes.

D. Equipment Availability

The production of armor as forgings does not contemplate the development of new methods, techniques, or processes.

The equipment discussed generally in this section and described in more detail elsewhere in this report is to be built according to known principles, established methods and with facilities available in this country at the present time.

While there is no press available to the Western World which is directly suitable for the production of hull noses, for example, the provision of this type of equipment is well within the scope of American engineering and production know-how. By the same token, furnace equipment to heat billets and provide the heat treating facilities can be produced within the present American practices.

The die making facilities available in this country as a result of the expansion provided the Air Force heavy press program are adequate to produce the dies required for the tank forgings. In addition, surveys conducted during that heavy press program have ascertained the availability of die materials for sufficiently large sizes to accommodate the production of the items required. The operation of the large forging installation required to produce tank forgings is within the range of work now being performed in this country by such organizations as The Aluminum Company of America forging plant in Cleveland, The Wyman-Gordon plant in North Grafton, Massachusetts, as well as the work being performed by the Ladish Company in Cudahy, Wisconsin; Cameron Iron Works in Houston, Texas, and others. The production and management techniques required for the operation of these large forging installations have been fully developed in this country and sufficient experience has been gained by a satisfactory number of qualified personnel to operate the complete facility.

E. Additional Operations

Once the forging, trimming, and heat treatment of the main structure of the tank nose is completed, conventional procedures will be followed in the continuing fabrication.

Parts of the tank structure which cannot conveniently be forged integrally with a main nose element will be attached by welding after appropriate pre-heating in special furnaces or by torch pre-heating of selected small elements and small areas of the main forging. In many cases these items to be attached by welding will of themselves be formed by forging on presses similar to the one described elsewhere in this report but of greatly smaller capacity.

In the manner described, major assemblies such as hulls consisting of hull noses, side plates and bottom plates, can be provided from individual, heat treated, welded, and stress relieved sub-assemblies. The plant designs and equipment specifications required to provide the facility in which these tank elements can be assembled into major sub-assemblies by welding are not part of the requirement of this contract and these facilities will not be discussed here. In connection with this work, however, it is to be pointed out that the principles involved in the production of major assemblies are fully developed and well known.

IX - CLOSED DIE FORGING PRESSES

Omitting the "ancient history" one can say that closed die forging, while known for a long time, came of age during World War II when it was first applied to the mass production of rigid parts made of non-ferrous metals (primarily aluminum alloys) for the Roosevelt-Arnold program of 50,000 planes annually.

The first heavy press program initiated at that time and carried out under the supervision of K. B. Wolfe (later Lieutenant General and Deputy Chief of Staff, Materiel, USAF) was dedicated primarily to extrusion presses, of which 100 were built.

The largest closed die forging press available to this country at that time was an 8,000 ton press (larger presses, including four 14,000 ton presses were in existence; however, their rigidity and the design in general were not conducive to their use for the closed die forging process).

The survey teams visiting Germany after World War II discovered the extensive use of large closed die forging presses in Germany. The process was immediately adopted by all countries and several German presses were removed and shipped abroad. Several presses, among others, one 33,000 ton and one 6,500 ton went to the USSR; two 16,500 ton and several smaller ones went to the United States.

In the course of events, the American Government and American industry became convinced that the increasing size of airplanes made it imperative to have available larger closed die forging presses.

The Korean War gave the final impulse for the start of the Second Heavy Press Program of the U. S. Air Force which resulted in the construction of two 50,000 ton and two 35,000 ton closed die forging presses (also several extrusion presses). These presses are installed and in operation in two Government owned plants, one operated by the Wyman-Gordon Company in North Grafton, Massachusetts, and the other operated by the Aluminum Company of America in Cleveland, Ohio.

The Alcoa plant in Cleveland is a facility limited to processing light metals only. The North Grafton plant, however, represents a facility capable of handling any metal (although the installed furnace capacity for ferrous metals is rather limited at present).

The switch from manned aircraft to missiles reduced the utilization of the two heavy press plants. However, the process itself and the technological advantages offered by it were proven beyond any doubt. A large number of parts for planes like the B-52, B-58, B-70 as well as for a vast variety of smaller fighter and reconnaissance planes of the Air Force and the Navy could not have been made within the required weight limitations without the availability of the heavy closed die forging presses.

It was impossible to foresee during the design and construction stages of the heavy press program what kind of pieces these presses would be required to produce. Therefore, the specifications of the heavy presses had to provide for their applicability to all kinds of configurations and sizes.

Generally speaking, these presses have large beds (about 15' x 33') as well as reasonable strokes (7') and daylight (12'-13') which makes them machines of a "universal" type.*

However, already in 1950, the industry discovered the great advantages that may be obtained from specialized machines

---

*The press designers were very happy with the large bed requirements; conventional multi-cylinder hydraulic systems could not have been accommodated except in combination with large beds. Equally happy were they with the acceptability of limited strokes and daylights. Unfortunately, both features make the existing presses unsuitable for the quantity production of heavy tank parts.

designed to produce a clearly defined class of products. This line of thought resulted (in 1950) in a rebuilding of the 7800 ton press at North Grafton to make it particularly adaptable to a combination forging and reverse extrusion procedure for the manufacture of hollow cylinders for landing gear of manned aircraft.

Along the same lines and at about the same time two special presses, 11,000 tons and 4000 tons respectively, were provided by the U. S. Navy for the Cameron Iron Works plant in Houston, Texas, for the manufacture of breech blocks for heavy guns and for other similar hollow forgings. It should also be noted that the Cameron plant is equipped for handling ferrous metals; as a matter of fact, it has no facilities for heating of non-ferrous metals.

The reduced volume of orders for manned aircraft induced the industry to explore the applicability of heavy presses for other lines of products.

As the result of these studies, the industry found ways to utilize efficiently the heavy presses in the manufacture of some vital missile parts.

One of the press utilization studies* undertaken in 1957 covered the feasibility of installing auxiliary systems for deep drawing of very large shapes with substantial wall thickness. In the course of this study it was discovered that, contrary to the conventional viewpoint, the present state of art permits the designs and construction of large hydraulic systems without the use of a multiplicity of hydraulic cylinders. This study resulted in the design of a system with a single main hydraulic cylinder of 50,000 ton capacity. The study also predicted the feasibility of similar systems of a much larger capacity.

Further conclusions of the study were:

a) the feasibility (and even the necessity) of smaller press beds resulting in more rigid and at the same time far less expensive press structures.

b) the easy adaptability of such systems to the production of other than aircraft parts, exemplified by: high-strength, low-weight vehicle wheels; land-vehicle wall panels and frames, etc.

---

* No U. S. Government funds were used in financing that study.

No action was taken on this study, and so it was with somewhat mixed feelings that the authors of this report and of the press utilization study of 1957 viewed at the World's Fair in Brussels in 1959 a press model exhibited by the USSR, incorporating a single 33,000 ton cylinder hydraulic system very similar to the one designed in this country.

The "mixed" feelings were due, on one hand, to the regret that another country, our "potential adversary", had again beaten us to the punch in a situation where the technological background and the engineering development were all in our favor; on the other hand, it was quite satisfying to find that other quite competent people shared our basic approach; it was also quite gratifying to see that our reduction of the basic idea to practice was far superior to the Russian structure.

In the meantime, reliable sources* report that the Russians have placed their 33,000 ton press in operation, are completing the erection of a 77,000 ton press, have designed and are considering the construction of a 110,000 ton press and a 220,000 ton press.

---

*Information on these sources will be provided if requested through proper channels.

The design of the 75,000 ton press recommended for the forging of tank parts and described elsewhere in this report follows the basic concept developed in 1957, but, of course, properly modified for the job in question. The suggested press is not a universal machine as are the heavy presses of the Air Force; it is rather a specialized piece of equipment that can efficiently produce complex pieces: tank noses in times of emergency-compact vehicle parts (wheels, panels, gas turbine discs and similar items) in peace times.

The use of cast billets as the starting material and the low conversion cost make the suggested process quite attractive. The possibility of avoiding the mothballing of the plant at any time enhances the project still more.

A description of the suggested press as well as proper conclusions and recommendations on the whole project are submitted elsewhere in this report.

SECTION III

ANALYSIS OF CURRENT AND NEW FABRICATING METHODS FOR THE MAIN BATTLE TANK

X - MANUFACTURE OF TANK HULLS

Introduction

Our study covers the design of the M-48 medium tank as well as the two models of the main battle tank - T-95 and M-60.

Pertinent data regarding the producibility of hull parts, in particular, the hull nose, were developed for all three models. However, our final recommendations refer to the main battle tank model M-60.

A. General Remarks

The engineering study of the detail drawings of the tank hulls for the M-48 and the main battle tank models reveals that the possibility of producing either tank hull as a one piece forging is remote.

No attempt could be made to die forge these parts with existing equipment nor with any equipment now planned or proposed for the foreseeable future.

Much time and effort and money have been expended by the industry in searching for means to provide multi-purpose presses combining the operations of forging, upsetting and piercing, extrusion and forming. Machines for the combined performance of these several operations have been made but these are of modest proportions, suited for the production of small parts only.

A tank hull approximately 21-1/2 feet long, 9 feet wide and about 4 feet high with inner and outer finished surfaces in three planes cannot be formed. Further, the concept of tank construction according to modern standards calling for the distribution of armor according to the ballistic resistance requirements poses serious problems in the moving of masses of metal. At the same time, portions of the structure of the rear of the hull and at the sides are primarily elements forming a not too heavy a frame carrying light loads. Production of a single piece combining these thin structures and the massive nose portion resistant to armor piercing projectiles would present insurmountable problems to press and die technologists.

The only feasible solution within the current state of art consists of separate forming of the hull nose and of the rest of the hull and then combining the separately formed parts into one monolithic hull by welding.

This section of the report analyzes the production of tank hulls from a series of forged and otherwise formed major components subsequently welded to form the ultimate monolithic hull.

B. Tank Hull Noses

Serial # 7

1. The hull body of the M-48 medium tank is shown on drawing 70-1126. The complete hull body is approximately 21' 3-3/4" long, and 8' 7-7/8" wide at the widest. As discussed in the preceding chapter A, this item cannot be produced as a single piece by any other than the casting method. Even when using the casting technique, the breaking up of the unit into several components has proven itself as quite competitive (pricewise and technologically) with the one piece hull.

In our study of this tank model we have approached the problem of production by the forging method by subdividing the tank hull into elements which can individually be produced on a forging press.

Serial # 5

The first and most critical portion of the tank hull is the nose, a visualization of which is shown on our drawing 70-1123. While two half-sections are shown constituting the nose forging, the forging proper would be produced as a single deep, tapered cup. This section is approximately 56-1/2" long, 102" wide, and 45-1/4" deep, and corresponds approximately to the section of the hull body

Serial # 7 — to the left of the plane AA on our drawing 70-1126. The weight is approximately 8,950 lbs, in steel, as

Serial # 4 — determined by the computation of our drawing 70-1122.

The detail of the forging of the nose of the hull body of

Serial # 3 — the M-48 model is shown on our drawing 70-1121. All of the original cast metal hull thicknesses, angles, metal distributions, etc. are carried over from the original cast designs of the M-48 hull.

We estimate that the production of the hull nose by forging would require a press of approximately 50,000 tons capacity. Presses of this capacity are in operation today; however, the substantial length of the forging (minimum trimmed length 49") determines press stroke and opening as well as press capacity. For the production of this nose, we would require a daylight opening (the maximum space between the opposing surfaces of the moving and fixed crossheads of a conventional forging press) considerably larger than what is available at the present.

A press of the required capacity, stroke and daylight is well within the present state of art. However, the exploration of the producibility of the hull of the medium tank, M-48 model, did not proceed any further because we were notified that this model was to be superseded by another of different design (main battle tank T-95, respectively M-60).

Summarizing the preliminary analysis one can say that the nose of the M-48 tank can be forged provided a new appropriate major piece of equipment is provided. Since the M-48 was replaced by the main battle tank, our attention was directed from here on to the latter unit.

Further below this problem is investigated in greater detail with reference to the main battle tank, and to our final recommendations regarding the forged nose.

2. The hull of the main battle tank was used next in the investigation of the producibility of tank hulls by forging.

The approach was substantially the same as described for the M-48 model. An important change was noted in the external contour of the hull, which presents a smoother, more continuous surface (our drawing 70-1125).* Note that the overall length of this hull model is shorter than that of the former, terminating 14'3" from the nose in an area at the rear to which portions for the enclosure of the engine, etc. are to be added. These portions are discussed separately elsewhere in this report. (They are to be manufactured from plate by conventional flame cutting, bending, and welding).

Note from the drawing 70-1125* as well as from our drawing 70-1127* that a shorter length of nose forging will be required for the main battle tank. Note also that the complexity of the external and internal bosses has been reduced resulting in a configuration which is more readily forgeable than the previous M-48 tank hull nose.

* Not included in this report.

The front idler wheel hubs are shown on drawing 70-1127* outside the dotted lines in the plan view. These would be added to the nose forging as welded-on separately forged bosses to provide the structural strength required for the idler mounting. Were these hubs to be forged integrally with the hull nose a problem of major proportions would result with the necessity for having a split die. We do not recommend this much more complex solution.

The main battle tank design was made available to us in two variants: as the T-95 and, later on, as the M-60.

The T-95 hull nose design differentiating this model from the original M-48 is that no extensive bottom plate is shown for the tank hull nose. The removal of the necessity to produce this integral bottom plate in addition to the massive top plate of this nose, makes the problem of forging this item less formidable. The orientation for production would be such that the direction of the forging stroke would be as shown by the arrow at A (drawing 70-1127).* With this arrangement the press capacity required would be approximately 40,000 tons and a stroke of 42 inches would suffice.

* Not included in this report.

The plan size of the forging approximately 74" x 54", is not excessive considering the size of shifting table available on the 50,000 ton machines already in operation in this country. A quotation has been received from the Wyman-Gordon Company of North Grafton, Massachusetts, offering to supply nose forgings to this drawing. Weighing approximately 2,100 lbs. less than the M-48 counterpart (shown on drawing 70-1121) this piece is within the range of capacity of existing American forging plants.

Serial
3

For all that, the T-95 variant is not under consideration at present and therefore our attention has been directed towards the M-60 model.

3. Based on the analysis of the details of the current model of the main battle tank hull and considering the capacity of forging equipment within the realm of equipment which can be visualized with our present technology, the forging of the tank hull nose as shown on drawing 70-1164 is proposed.

Serial # 8

With a trimmed weight of approximately 10,100 lbs, in steel, the forging is approximately 58-1/4" long, 96-3/4" at its widest, and is 45-1/4" deep. The production of this forging represents a press load which would be almost concentric with the center line of the forging press. While the graphic center line of the section in view DD does not precisely coincide with the center line of the press, the positioning of this axis would not present an eccentricity situation which would exceed the allowable load eccentricity of the machine. Note in the plan view that the front idler wheel hubs are not to be included as integral parts of the forging but are to be added in a subsequent welding operation.

At its largest area, the size of the punch is approximately 3,265 square inches. The contour of the punch tapers from the forward edge, increasing at an angle of approximately 55° - 60° to the size required at the aft section where the welding to the sides of the hull body will occur.

In the production of the recommended forging, the portion of the stroke which requires the largest press capacity occurs at the very start during the initial penetration of the billet when the metal is initially forced into the forward nose portions of the die. The force for this heaviest work is provided by the action of a section of the punch with a comparatively small area. Under these circumstances, the larger specific tonnage required for the initial penetration of the billet is available due to the decreased size of the punch.

The production of the upper glacis, one inch thick, and the lower face, 1-3/4" thick, as well as the side surfaces which taper from 1" to 1-1/2", is accomplished as a rearward extrusion of the steel with the semi-plastic metal throwing backwards over the punch during the latter portion of the stroke.

This nose forging is produced with the greatest portion of the mass at the forward end of the nose, with the comparatively thin top, bottom, and side faces produced as back extrusions. Under these circumstances, only a limited amount of excess metal must be incorporated into the original billet. This excess metal, to be trimmed prior to welding with the side plates, will not amount to more than 5% - 7% of the net weight of the forging. This surplus metal is trimmed off and recirculated to the cast shop as melting scrap.

The design of the dies suitable for production runs on this nose forging will have to include special consideration for the features outlined below. These are in accordance with the conventional die making principles and practices.

1. Wear of the die at critical points and curves must be considered, and inserts made of metal with special wear resisting characteristics provided in the die.
2. The heat generated in the die during the working of metal in certain critical areas of the forging will have to be removed.

3. Provision will have to be made in the metal punch for an ejecting mechanism allowing the forging to be removed from the punch.

4. Provision will be made in the female die for an ejecting mechanism if the forging should preferentially stick in the latter member.

5. Differential cooling of the various punch and die sections will be required to compensate for the unequal flow from the billet of heat transmitted to the die during the forging operation.

We calculate that to produce the hull nose for the main battle tank a press of minimum 70,000 tons capacity, with a high pressure stroke in the order of 5 feet and with a daylight of approximately 18 feet will be required. The exact design requirements and suggested specifications for this special machine are given elsewhere in this report.

XI - MANUFACTURE OF THE TOP, SIDEPLATES AND REAR OF THE HULL FROM PLATE

A. Introductory Remarks

The manufacture of the hull noses was discussed in Unit X. This Unit XI covers our recommendations with regard to the remaining portion of the hull.

An examination of the detail drawings of the tank hulls of the medium tank M-48 and the main battle tank reveals a significant change of approach to the design of the main hull portions aft of the hull nose. The sideplates of the M-48 model show the conventional cast, concave outer surface of the sideplates. Immediately succeeding this concept came that of the model, which, while still a steel casting, showed sideplates which were essentially straight and vertical, with an equally simplified top plate and gun turret ring cast integrally. Most recently we have become aware of a revision of the main battle tank design shown

Serial # 8 on our drawing 70-1164.

Our analysis of this situation has revealed some characteristics common to the medium and to the main battle tanks which indicate that the production of either of these designs from welded steel plate as opposed to casting is feasible.

B. Manufacture of the Main Portion of the Hull

Serial # 7

Our drawings 70-1126 (hull body) and 70-1124 (side of hull body) show the side of the hull body aft of the hull nose which extends rearward approximately 38'-4-1/2" to form the sides of the hull.

Serial # 6

These sideplates could be produced from rolled armor plate in the cross sections shown in the views AA and BB of drawing 70-1124 by a direct closed die forging. We estimate, however, that the production of the complete sideplate as a single piece according to the drawing would require a forging press of approximately 95,000 tons capacity, with a bed approximately 12 feet by 24 feet. While the bed size requirement is met by presses now in domestic operation, the capacity is almost twice that now available.

Our drawings 70-1125* (hull front section) and 70-1128* (side of hull) refer to the T-95 version of the main battle tank. This element could be produced in two parts, neither of which requires new equipment, both parts to be

---

* Not included in this report.

joined by welding. As shown on the latter drawing, a forging would be produced of the section forward of the plane AA. In similar manner, rolled armor plate would be forged to provide the inverted U shape of the portion of the hull aft of the plane BB. A turret mounting ring would be rolled from bar stock or processed from rolled plate. A composite of this tank hull could thus be manufactured completely avoiding any castings.

The final design of the main battle tank hull body (M-60) is an interesting simplification of the design of the M-48 calling for a return to the concave external shape but shortening the sideplates (see our drawing 70-1124).

The common characteristics of these three designs have led us to the following conclusions:

a) The present method of manufacture has not imposed any serious restrictions on the designer with regard to changes in wall thickness.

The plate fabrication method of production would be more efficient if the variations in thickness could be reduced. Preliminary discussions with the representatives of OTAC disclosed the possibility of modifications of the design towards a more uniform wall thickness. Such modifications which would facilitate the job would, of course, be predicated on:

1. the stress analysis not showing any unacceptable increase in the stresses
2. the total weight of the hull not being increased.

b) Some of the crimping presses considered for the reinforcement of the areas around holes are powerful enough to permit a certain amount of metal movement from areas of lesser wall thickness to adjacent areas where a heavier wall is required. Therefore, the increase in the uniformity of the wall thickness is desirable but not a decisive requirement.

We would point out, in addition, that the reinforcing pads around various holes and other openings in the hull can be produced either by crimping (hot die piercing of specifically heated small areas) or by welding of pads; the relative merits of both systems must be investigated during the proposed detail processing.

Therefore, we recommend that the side plates of the main battle tank hull be split into two pieces on each side and fabricated from plate utilizing such well established techniques as plate bending, crimping and welding.

If this report results in further steps towards the introduction of the recommended method into actual manufacturing, the very next step should include as an integral part a complete processing of the fabrication of main hull portion aft of the nose from plate.

XII - TANK TURRETS

A. Preliminary Remarks

Forged steel, by virtue of its great strength and toughness, offers greater dependability and longer life than is possible with use of equivalent sections produced as castings. Furthermore, another advantage of considerable magnitude is the saving in metal weight cost of a forged steel part because less metal is required to be removed from the more accurately sized forged piece. The first approach to the forging of tank turrets was to determine the possibility of forging a turret for a medium tank in one piece. A quick examination of the two turret designs for the medium and main battle tanks respectively reveals that the production of either piece by a forging process is not possible with the equipment for forging now in operation in the United States, nor with the equipment contemplated for installation in this country, nor, even, with any new equipment within the present state of art.

B. M-48 Turret

Referring to the turret of the M-48 medium tank, please see our drawing 70-1130.

This turret contains a large "undercut" surface (see area A) which cannot be die forged in pieces of this size. While it has been feasible in years gone by to produce such undercut vessels and urn shaped pieces in other metals, the technique for hydraulic or mechanical expansion which is required in this operation has not been developed to include work pieces much larger than door knobs, lipstick cases, etc. At the outset, it is apparent that were the turret to be made as a forging, a separate underpan corresponding to the cross-hatched portion (see plan view of 70-1130) would have to be welded in place under the counterweight.

Serial # 10

Analyzing this drawing in further detail, a considerable difference in metal wall thickness exists between the section which approximates 7 inches thick at the front of the turret and that which is approximately 2 inches thick at the rear. Forging would require the moving of a considerable mass of metal during the pressing operation.

If one assumes that the cross section of the starting metal billet would be sized to suit the heaviest wall, the problem is to produce a cup shaped piece of grossly unequal wall thicknesses and this problem would not be overcome without producing hot tears in the metal.

In the turret of the main battle tank (our drawing 70-1129*), in addition to the above described large variation in wall thickness between vertically disposed surfaces in the front and in the rear, a considerable difference exists in wall thickness along sections taken transversely to the center line of the vehicle. This has been established in the original design to provide the additional protection and ballistic security required for the vehicle operator side of the tank. In forging, the center of pressure must be located within a small circle of permissible eccentricity. The corresponding space requirement demands that approximately a 15-1/2 feet long and approximately 12 feet wide bed be provided. Add to this size the wall and the resultant bed area is about 100% larger than that of any existing closed die forging press.

---

* Not included in this report.

Since a considerable portion of the estimated weight (see drawing 70-1129*) of the turret (12,500 pounds) lies in a plane perpendicular to the direction of forging on a press, the provision of bosses and pads on the top surface for the mounting of hatches, manholes and weapons becomes largely a matter of "coining" these appurtenances into the surface. A coining operation requires extraordinarily high instantaneous specific forging effort and it is estimated that an average requirement of 80 tons per square inch would form the contours. Under these circumstances, a press about twice the size of existing machinery (100,000 tons plus capacity) would be required. Therefore coining operations cannot be considered for our project.

The production of a one piece forging of the size and complexity of the tank turret is beyond the scope of the state of the art today and one piece closed die forging for the tank turret of the M-48 and the main battle tank is not recommended at present.

With the production of one piece closed die forgings of tank turrets contra-indicated, we have attempted to subdivide the turret into producible elements, considering that forgings of individual components would be produced, trimmed, and machine

---

* Not included in this report.

welded together on holding jigs and fixtures, which would be especially designed for this purpose.

Drawing 70-1141 shows one such composite turret for the medium M-48 tank in which the tank turret is divided into five parts plus the underpan referred to above. Each of the elements in the composite piece would be in themselves producible by forging, in closed dies, on existing equipment, with a minimum of trimming and edge preparation and would be welded into homogeneous tank turret. Drawing 70-1142, Composite "C", detail other ways in which turret could be subdivided to achieve the desired result. The drawings numbered 70-1135, 70-1136, 70-1137, 70-1153, 70-1134, 70-1138, 70-1139, 70-1140, 70-1144, 70-1145, 70-1162, and 70-1163, show the development in three planes of each of the component parts of these three composite tank turrets, indicating that each portion of itself could be produced as a closed die forging on equipment not greater than what is available today.

Serial # 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25

The continuing analysis of the composite sectioning of the tank turret reveals that Composite "B" (70-1142) while rather attractive in general, requires that more consideration be given to the individual sections with respect to the uniformity in thickness.

In view of this aspect, an additional section would have to be forged and the turret would consist of six portions. As shown on Composite "B", Section III-B has a uniform thickness of 1 inch. This section could be stamped from a 1 inch thick plate.

Notice also that all the sections which would be welded to the Section III-B have adjoining edge thicknesses 1 inch thick. This would result in a uniform welding seam of 1 inch thickness at the perimeter to Section III-B. An attempt has been made to eliminate Sector VI-B by distributing this area and adding it to Sectors IV-B and V-B. It was quickly seen that the projected areas of these sectors (IV-B and V-B) would be more than the largest existing presses can handle and that a six piece subdivided turret would be necessary. Subdividing the tank turret into six pieces as opposed to five would result in more uniformity of thickness among the pieces but would also result in a marked increase in the linear distance to be welded in the assembly operation.

Serial # 20

In Composite "C" (70-1143) the tank turret was divided into four sectors and in this analysis it was decided to obtain the largest projected area possible per section and at the same time keep the welding to a minimum. This would require the existing press to operate at its maximum capacity of 50,000 tons.

Note that in Composite A and B, the nose of the turret was split in two and the thickness of the individual sections varied from 1 inch to 7 inches. In Composite C, however, Sector 1C shows the nose of the turret as one piece with a variation in thickness from 3 to 7 inches. It is also to be noted that the projected area of this section has increased to the maximum of allowable limits. The remaining sections of the turret have varying thicknesses from 1 inch to 3 inches.

Welding the sections of the turret in Composite C was held to a minimum. Note also that the sections were again divided through the hatchways to further minimize the amount of welding required.

We consider Composite C to be a more efficient method from the standpoint of forgeability and weldability as either Composite A or Composite B.

Conclusion

Since the consideration taken into account in these analyses was to determine whether forging and welding the turrets had any advantages over casting the turret, no thought has been given to the problem of ballistic resistance.

We have attempted to produce the turret by subdividing it into the least number of forged sections and holding the welding time to a minimum. The sections with large projected areas and wide variations in thickness present a problem in distribution and of metal flow. It is also to be noted that a large amount of welding will be required in assembling the turret, not only in the length of the welds but also in the depth of welds.

In view of the fact that these sections would require a long time in handling, heating and welding, we have come to the conclusion that there would not be any economic advantage in the forging of the turrets over the original method of casting.

With the production of the hull as forgings and plate assembly, sufficient foundry capacity becomes available to reduce the problem of lead time to a minimum.

It is our recommendation therefore that this element of the main battle tank not be produced as a forging but continued as a casting for the time being.

SECTION IV

PROCESS AND PLANTS

SECTION IV (contd)

XIII - DESIGN OF THE PROPOSED 75,000 TON PRESS

As stated elsewhere in this report, a 75,000 ton forging press is recommended as the major piece of equipment for the nose forging facility.

The scope of work stipulated for this report requires only the formulation of a performance specification but does not provide for an engineering study of the press design.

We feel, however, that setting up of a performance specification without a design analysis would not answer basic questions concerning the feasibility of the suggested process:

1) Is the required equipment producible?
2) What are (very approximately) the costs of such equipment?
3) Is the suggested design not only producible, but, once produced, is it operable?
4) If it is operable, is it practical?

No budget for the required analysis has been included in the cost estimate for this report, nor is such analysis included in the statement of work for this report.

It is, therefore, rather fortunate that our organization has available the necessary information and that it can be utilized for the purposes of this report without incurring cost chargeable to this contract.

The information in question was developed by our staff for another project of our own. In making it available for this report, we retain all proprietary rights and do not convey to the Government any shop rights, patent licenses or any other rights regarding the design of the press in question. We repeat once more that the design layout of the required forging press is not covered by the statement of work of this contract nor have we charged to this contract any expense in connection with this design study.

The design concept of the suggested press is shown on drawing
Serial # 2 12-1018. Also attached is the Russian concept of a similar
Serial # 1 press (Sketch 306).

It should be noted that

1. our design concept was developed prior to our knowledge of the Russian concept.
2. our design concept shows substantial differences when compared with the Russian concept.
3. our design concept shows substantial advantages when compared with the Russian concept.

4. the Russians have built at least one (and probably more) 33,000 ton press of this type, at least one 77,000 ton press; they have designed, and possibly built a 110,000 ton press; they have designed, but not built a 220,000 ton press.

Serial # 2

The single cylinder press (drawing 12-1018) is hydraulically operated through intensifier (s). The press is upward acting. The circumferentially disposed tension members are arranged to allow the passage of the die table from and to the center line of the press. A concentrically mounted ejection cylinder and ram are located within the main ram and of sufficient capacity to enable the most complex forging to be ejected from the die.

The control system for this press has the following specific capabilities:

In addition to a stepless manual control, it provides for the automatic control of a number of preselected speeds, and preselected forging strokes; preselected forging force can be exerted by the moving platen during the forging stroke with the maximum tonnage limitation having precedence over the programmed speed control. It also provides a minimum of four stroke positions for automatic actuation of the speed control, provides for the actuation of the start of the controlled stroke at any point in the automatic programmed cycles; provides remote manual control, so designed, as to override the automatic system at any point in the cycle, with the exception that the preset maximum press force limit cannot be exceeded.

The provision of controls for the press operations in accordance with the above specifications will allow the performance of forging operations on a wide range of metals.

In addition to the press controls described above, an external staging of pressure is provided by means of the 1:2 intensifier. Bypassing the intensifier system, one can operate at 37,500 tons directly from the accumulator station providing for economy of operation.

The hydraulic closed die forging press is actuated by fluid medium from the Water Power Station. High pressure fluid, from the discharge ends of direct acting plunger pumps is delivered to large cylindrical hydro-pneumatic accumulator bottles in which the pressure fluid is stored against a pneumatic cushion, to be released through suitable valving to the press parts and auxiliaries during the pressing operation. The direct acting plunger pumps are driven by mill type synchronous motors at slow speeds to develop the 5,000 psi accumulator pressure. A series of cylindrical tanks operating between the pressures 4,500 psi low -- 5,000 psi high, stores the high pressure water until it is required by the press. In addition to the actuation of the differential plunger of the main cylinder, the high pressure is used to activate other cylinders of the press such as the return cylinders, the ejection cylinder (s), and the die slide and table shift actuating cylinders. The closing motion of the main ram (the idling stroke) is accomplished with the use of hydraulic fluid from the prefill vessel, ordinarily about 100 to 200 psi pressure which suffices to cause the press to close during the prefilling advance. In addition to the equipment listed above, large multi-stage air compressors rated at maximum 5,000 psi delivery are used to supply and maintain the high pressure air which keeps the accumulator bottles at operating pressure. While the compressors are of comparatively small delivery volume, they should have the ability to initially charge the system with air at a reduced pressure, within a period of 2-3 days. A large water tank of sufficient capacity to supply the pumps with low pressure water during the operation is provided. The water tank is of welded sheet steel construction with spun or dished steel heads and is to be provided with heat exchanger apparatus for maintaining the proper water temperature. During the operation of the station and press, the water temperature will rise, and it will be necessary for the heat exchangers to remove heat from the water to keep the operating temperature of the fluid at a level which will not be injurious to the packings of the press and the pumps. Under circumstances of prolonged shutdown, or of very cold weather, it may be necessary to use the heat exchangers to bring the temperature of the water to an operating minimum of approximately 50°F.

The prefill tanks will supply the prefill water to the main cylinder in large quantities necessary to bring about the prefill strokes. After the completion of the forging portion of the stroke which is accomplished by fluid from the hydro pneumatic accumulator station, either directly or via the intensifiers, the main cylinder motion is reversed and the water in this cylinder is returned to the prefill tank. The excess water in the cylinder, which was supplied at high pressure during the forging stroke, is returned to the prefill vessel through the back pressure relief valve and thence to the water tank, serving as supply for the pumps.

SECTION XIV - OVERALL PROCESS AND PLANT LAYOUT

A. Scope of Process Analysis

Our report assignment calls for a general review of four types of installations:

1. An isolated, self-contained plant, without melting facilities and without regard to existing Government owned facilities.
2. An isolated, self-contained plant, with melting facilities and without regard to existing Government owned facilities.
3. A forging plant, integrated into existing steel melting Government owned facilities, capable of producing the ingots required for the forging process.
4. A forging plant, integrated into existing Government owned forging facilities capable of providing supporting services and, particularly, the forging and die servicing know-how.

B. Basic Operating Data for the Contemplated Facilities

For the purposes of this report the required production rate for the main battle tank is assumed with 3, 300 units per month. The annual production of forged tank hull fronts would be, then, a minimum of 39, 600 units. It is further assumed that this production rate represents the maximum effort and that, therefore, no spare capacity is required.

Based on these assumptions and for the maximum utilization of the contemplated facility on a balanced basis, the operations of the several major sub-divisions of the facility are planned on the following basis:

Installation Type	Melt and Pour Departments
2 and 3	24 hours per day, 7 days per week Total: 168 hours per week production time
2 and 3	Mold Shop
	16 hours per day, 6 days per week Total: 96 hours per week production time*

* It should be noted that the plant output is limited not by the work load on the forging facilities but by the size of the melting and heat treating departments. Consequently, following steps could produce a substantially increased production (should it be required):

a) Heat Treating and Welding Departments would have to be increased.
b) Ingot melting and forming would have to be increased (unless proper ingots can be obtained from an outside source).
c) No changes in other departments, including forge shops, would be required.

Installation Type	Closed Die Forging Department
1, 2, 3, 4	16 hours per day, 5 days per week Total: 80 hours per week production time
1, 2, 3, 4	**Heat Treating Department** 24 hours per day, 7 days per week Total: 168 hours per week production time
1, 2, 3, 4	**Inspection Department** 16 hours per day, 6 days per week Total: 96 hours per week production time

C. Schematic of the Material Flow

The discussion of the material flow will refer primarily to

Serial # 27	Drawing 1497	Process Flow Chart for Ingot Casting Facilities
Serial # 26	Drawing 1496	Process Flow Chart for Forging Tank Hull Fronts

These pictorial schematics describe the major elements of the different steps involved in the respective processes.

1. Process Flow Chart for Ingot Casting Facility

As shown on drawing 1497, an alloy casting plant will have a substantial storage area devoted to the stock piling of the three major elements used in the preparation of an alloy ingot. Scrap storage, pig iron storage, and alloy storage areas deliver the required quantities of respective materials to the analysis and weighing station in which the composition of the melt may be proportioned. Following this step, the material proceeds to the charging and melting furnace stations where the charge is brought to heat, melted and brought to pouring temperature. Finally, molten metal is tapped. At the ingot casting station, the ingot molds are filled with molten metal and, after a short time interval allowing the outer layers of the ingot to solidify, delivered to the stripping and cooling station while the pouring ladle is returned to the ladle maintenance section for preparation of subsequent pours. The molds are stripped from the ingots and are returned to the mold maintenance department while the ingots are permitted to cool further prior to the ingot inspection procedure.

After reinspection, ingots are put into the ingot storage area preparatory for delivery to the forging area.

Providing pouring pits to keep at least a portion of ingots hot and, thus, reduce the reheating cost should be considered during the next stage of this project.

Serial
26

2. Process Flow Chart for Forging Tank Hull Fronts (See drawing 1496)

The receiving station receives and prepares cast billets for storage.

If the billets are cast in foundry constituting a facility integrated with the forge shop, the ingots are cleaned and brought to final size, as outlined in the preceding section, whereupon they can be stored immediately upon receipt. Ingots produced by other sources may require additional preparation before being judged suitable for forging.

After heating to forging temperature in the rotaty billet heating furnace, as shown on the flow chart, the billet is blocked into a shape roughly corresponding to the overall dimensions of the first 10 - 12 inches of the die in the longitudinal direction. This operation produces a triangular prism just small enough to be inserted into the female die member. This prepares the billet for forging.

After removal from the billet blocking station, the metal is returned to the billet heating furnace where the heat loss during the blocking operation is restored in the "flame wash" oven.

The closed die forging operation proceeds, forming the massive hull nose section in the main press.

In order to insure that all of the die portions will be completely filled during the forging operation, a small excess of metal is provided in the ingot going into the die forging press. Upon removal from the closed die, the excess metal is removed from the rough forging by the mechanical trimming press.

On cooling, the forgings are cleaned, examined for soundness and size and the layout for the addition of welded appurtenances completed. These additional axle hubs, hooks, clamping, bolting, etc. as well as openings are provided on or in the forging by secondary welding and cutting operations, performed with the help of appropriate equipment.

On cooling after the welding and cutting operations, the forging is positioned on the heat treat furnace wagon for transport to the hardening furnace. Should detrimental stresses result from the gas heating and welding of the previous operations, these can be removed from the short tank hull nose by selective treatment of the forging on the furnace wagon. The hardening operation is carried out at temperatures high enough to permit small distortions to be removed from the forging by stress relieving during this operation.

On achieving the proper temperature for the desired length of time, the hardening furnace wagon with the tank hull nose is removed from the furnace and the forging quenched as the next step in the process of developing proper physical properties. While still on this furnace wagon the hull nose is placed into the drawing furnace where in the proper time and at the proper temperature the drawing operation takes place.

After removal from the drawing furnace, the substantially cooled part again is cleaned and inspected for dimensional accuracy. Depending on the results of this inspection, the shimming procedure on the furnace wagon may be altered, or the quenching procedure may require adjustment, or, in the case of severe distortions, the forgings might be returned to a cold straightening press where a slow hydraulic action would be used to cold bend the forging to the proper configuration.

If the tank noses are to be welded to the balance of the hull structure at an outside facility, they may now be prepared for shipment. If, however, the welding procedure will be carried on at a nearby facility, the tank hull noses may be stored after completion of proper inspection and marking.

D. Isolated Forge Shop Without Melting Capacity

1. General

Serial # 26

The material flow as shown on drawing 1496 has been discussed briefly in Item C.

Drawing 1496 shows the layout of the contemplated facility. As shown on this drawing, the plant provides equipment and auxiliaries to produce the number of units described above. It will measure 825 feet by 420 feet for a total area of 347,500 square feet.

The plant proper is divided into longitudinal bays 84 feet wide, with each bay covered by sufficient overhead travelling cranes to efficiently service the particular work areas located in the bay.

2. Departmental Break-down

The forging shop is divided into three main department groups:

a) Service Departments

First group, located in the first 625 running feet of Bay #1.

(1) Receiving and Shipping

(2) Billet Weighing and Cutting

(3) Layout

(4) Forging Inspection

Total area for 1 - 4:- 16,800 square feet.

Second group, located in Bay #4:

(5) Straightening and Shimming Section occupying 16,800 square feet

(6) Maintenance Department occupying 8,400 sq. ft.

(7) Die Storage area occupying 7,500 sq. ft.

Third group, located in Bay #5:

(8) Administrative and Office area occupying 12,600 square feet

(9) Inspection area occupying 8,400 square feet

(10) Layout for Welding and Flame Cutting occupying 8,400 square feet

(11) Welding and Flame Cutting occupying 8,400 sq. ft.

b) Furnace Group

(1) Rotary hearth furnaces occupying approximately 19,000 square feet

(2) Reheat (flame wash) furnaces occupying 8,400 square feet

(3) Die Heating Furnaces occupying 4,200 square feet

(4) Heat Treating Department occupying 16,800 square feet

(5) Forging Inspection Department occupying 16,800 square feet

c) Press Group

(1) Press forging occupying 35,700 square feet

(2) Water Power Station (accumumulators and pumps) occupying 14,700 square feet

(3) Forging Inspection occupying 16,800 square feet

(4) Forging storage occupying 16,800 square feet.

3. Material Flow through the Forge Shop (see drawing 1498)

A general description of the progress of material through the forge plant follows:

Billets are delivered from an outside source by railroad to the Receiving Department located in the left hand end of Bay #1. The removal of the billets from railroad cars, storing them and transferring billets to the weighing and cutting section is accomplished by utilizing two overhead travelling cranes within this Receiving Department.

Two fork lift trucks equipped with crane attachments capable of lifting five ton billets facilitate the handling of the material between the scale and the sawing tables. A third overhead travelling crane expedites the temporary storage of the trimmed billets and deposits the billets as required onto a flat transfer car.

The loaded flat transfer car of trimmed billets is conveyed across the bay to an area in front of and adjacent to the three rotary hearth furnaces. Billets are unloaded from the flat car by an overhead travelling crane either onto the floor along side the travelling flat car or if the loading schedule permits, located in front of one of the three rotary hearth furnaces. The billets are placed in such a manner to enable the mobile furnace charger to lift, grip, and to insert a billet into a rotary furnace.

The removal, transfer, and inserting of billets is a sequence of operations performed alternately among the three rotary furnaces by two mobile furnace charging machines.

The heated billet is removed from the hearth of a rotary furnace by a mobile forging manipulator. Completing the transfer, the furnace is immediately recharged with a new billet by a furnace charger.

The mobile forging manipulator places the heated billet on the blocking press. Here the billet is pre-forged into the shape of a triangular prism. The length of the prism is approximately the same as the width of the female die. The re-formed shape, when completed, is removed by the manipulator. The fork lift truck conveys this pre-forging from the manipulator over to and for inserting into one of the two reheat (flame wash) furnaces. Two fork trucks will ply between the pre-forge press and the reheat furnaces and from the reheat furnaces to the final forging press.

The pre-forging is reheated in the reheat furnace to obtain the appropriate temperature and to obtain an even distribution of heat in the forging. At the same time the heat lost by the billet during the pre-forging operation is restored to the billet. At the completion of the reheat operation, the billet is removed by a fork lift truck and carried over to and deposited upon the die table of the final forging press.

After the completion of the forging step in the large forging press, the piece emerges as a completed tank hull front nose forging. A certain amount of flash will have been formed during the forging stroke and this will be removed by the mechanically operated forging trim press. The nose forging is delivered to the trim press from the forging press by a fork lift truck.

When the trimming operation is completed, the nose forging is removed by a fork lift truck and transferred over to a temporary storage area prior to inspection.*

Within the storage area, which is serviced by an overhead travelling crane, the individual nose forgings are mounted on a specially designed dolly which possesses means of

---

* Prior to inspection a thorough sandblasting operation takes place.

rotating the forging to facilitate the inspection, the welding and the flame cutting of openings. The welding required may also be performed without removing the nose forging from the dolly.

This dolly is attached onto a continuous draw-chain conveyor system that runs just below the surface of the floor to the following departments: Inspection, Layout, Welding and Flame Cutting, Shimming Area, and finally back into the Inspection Department. As the dolly is conveyed through the various departments it can be detached from the chain conveyor system to be shunted aside to enable the department to perform the necessary work without blocking the progress of the conveyor.

Inspection of the nose piece forging determines the critical dimensional aspects as well as the soundness of the forging itself.

The function of the Layout Department is to draw and describe the exact locations of openings that have to be burnt, lugs, pads, bosses, etc., that are to be added to the surface of the forging.

All welding is done prior to flame cutting. The components that are to be welded onto the nose forging are prepared and cut to size at the Cutting Department and are brought to the welding station on carts towed by rubber tired gas powered tow trucks.

When the flame cutting of openings in the forging is completed, the dolly mounted nose forging is conveyed over into the straightening and shimming area. During the welding and the flame cutting operations some distortions of the nose forging will result. The nose forging is shimmed in such a manner as to insure that it will straighten itself out while it is at an elevated temperature in transit through the furnace.

The use of a multiplicity of nose forging transferring dollies will not be required since the revolving dolly on which the forging is first placed after its operation at the trimming press, will also be a furnace charging dolly and no trans-shipment of the forging will be required. The dolly mounted shimmed up nose forging is towed to the heat treating furnace by a rubber tired gas powered tow truck. Here the dolly is attached to a conveyor line which will deliver the dolly to and through the furnace.

There will be three groups of heat treating furnaces. Each group consists of a hardening furnace through which the shimmed nose forging traverses the full length, out the rear and into a quenching tank area.

In the quenching area the quenching fluid (water) will be applied and the temperature of the piece lowered through the methof of selective quenching as described elsewhere in this report.

Continuing around and turning 180° to the long axis of the hardening furnace the dolly will enter the drawing furnace which is located along side of the hardening furnace. Through precautionary measures undertaken to reduce the cause of distortion of the nose forging during the heat treating cycle, the primary cause of distortion eliminated. Beyond the heat treat stage, distortion will be removed by cold pressing at the straightening press.

Emerging from the drawing furnace, the nose is removed from the dolly and the dolly is returned to the area adjacent to the trim press. The nose forgings are cleaned and then unloaded by fork lift truck and deposited in a given area near the straightening press. The oil hydraulic straightening press is used to remove final heat treating distortions. This press is serviced by a fork lift truck. When the straightening process is completed, the nose forging is placed on a flat transfer car and is then loaded and, when loaded, transferred into the Inspection Department.

Two overhead travelling cranes are employed within the Inspection Department to unload forgings from the flat transfer car and to facilitate the handling of the nose forgings at the inspection station. Here the final inspection of the nose piece is performed for a seal of acceptance.

Having completed the inspection, the nose forgings are transferred to the Shipping Department. The handling for storage and shipping aboard railroad cars is done by two overhead travelling cranes. A completely finished nose forging is shipped by rail transport to a remote assembly area.

E. Self-Contained Facility Consisting of a Forging Plant and Ingot Producing Foundry

Serial # 26, 27
Serial # 31

The material flow through this plant was discussed briefly in Section 3, D above and is shown on drawings 1496 and 1497. A proposed plant layout is shown in drawing 1499 which describes the location of the forge shop and the melt shop in relation to one another and the placement of the scrap pile yard.

A complete casting and forging installation will constitute two major subdivions; the first being the melt shop to be described below, and the second being the forge shop as was described in the preceding Section 3. The following explanatory description will describe how the complete unit has been laid out so that the various major pieces of equipment to be used in the manufacture of forged tank hull nose fronts, such as electric melt furnaces, the heat treating furnaces, the forging presses, are all strategically located with reference to each other to provide a smooth flow of the material.

Serial # 31

As shown in drawing #1499, the melt shop consists of a large building including the major melting, pouring, and cleaning facilities and an externally positioned scrap yard. The scrap storage yard is approximately 825 feet, running alongside the melt building and is serviced by a double track railroad spur for the delivery of casting scrap. Also in this area is the yard for the storage of cast scrap, the recirculated material appearing as risers, shrink heads, etc., which is trimmed from the finished castings and is recirculated through the foundry. In the scrap year is an alligator shear to be used for the cutting up of heavy scrap. A scrap bailer is provided to form bundles of lighter scrap. Two overhead travelling cranes with magnetic lifting heads are utilized in the steel scrap handling. Prepared scrap is placed into a charging bucket and weighed. The bucket-mounting transfer car, running on standard gauge railroad track, will convey the charge from the scrap yard into the melt shop proper.

The overall scrap yard is approximately 150 feet wide and is located between the side of the melt building and the double track railroad spur.

The melt shop building will comprise 25 bays on 25 foot centers lengthwise with 4 bays on 84 foot centers in width. The entire building occupies 215,000 square feet of floor space. Each of the 84 foot wide bays runs the full length of the building and is serviced by a series of cranes on full width span runways.

The melt shop is subdivided into three main department groups:

a. <u>Pouring Area</u>

The major pouring area consists of approximately 62,500 sq. ft. of floor. Of this area, about 50,000 sq. ft. is occupied by the three 125 tons electric furnaces, the balance being devoted to the pouring area proper. Both the furnace area, including the electrical department, and the pouring areas, are serviced by individual overhead travelling cranes.

b. <u>Service Departments</u>

The service departments in the melt shop are the following:

(1) Ladle maintenance, approximately 10,000 sq. ft.

(2) Electrical department which is shown as a portion of the electric furnace area. It occupies 11,000 sq. ft.

(3) The furnace refractory storage occupying 17,000 sq. ft.

(4) The metallurgical laboratory occupying approximately 5,600 sq. ft.

(5) The mold cooling and stripping area occupying approximately 11,000 sq. ft.

(6) The mold maintenance area occupying approximately 11,000 sq. ft.

In addition, the third major subdivision of the mold shop is the storage area. This storage area consists of the following subdivisions:

(1) Alloy bins occupying 7,000 sq. ft.

(2) Iron ore storage occupying 13,000 sq. ft.

(3) Coke storage occupying 13,000 sq. ft.

(4) Limestone-silica sand storage occupying 13,000 sq. ft.

A general description of the progress of material through the melt shop is described below.

Starting at the scrap yard, overhead travelling cranes of the magnetic type are utilized to load the scrap for preparation before introduction into the melt. The prepared scrap is placed into a charging bucket and weighed. Alloying elements are added to the melt. A bucket-mounting transfer car running on standard gauge railroad track will convey the charge from the scrap yard over and into the melt shop.

The electric arc furnaces are top charged, having roofs that are hydraulically lifted and swung aside to permit the scrap to be dropped into the furnace from the bucket which is carried over the furnaces by the overhead crane.

At the conclusion of a melt, the steel is tapped into a ladle carried by a longitudinally moving overhead crane and brought into the pouring area. The steel is poured into molds on a flat transfer car. The empty ladle is placed on a "ladle mounting" transfer car and delivered then to the ladle area. The filled ingot molds are conveyed across the floor to the mold cooling and stripping department. The stripping of the mold from the cast ingot is accomplished and the billets are stored for further cooling. The molds are channeled to the mold maintenance department where they are cleaned, patched and readied for subsequent pours.

While the handling of molds and billets is by overhead travelling crane, the delivery of ingots from the melt shop to the forge shop is done on a flat transfer car running on standard railroad tracks between the melt shop and the forge shop.

The forge shop proper is identical with the one described in Section D.

F. Integration of the Contemplated Forging Facility into a Government Owned Foundry

The conditions of our contract require a layout of the necessary equipment and facilities which can be advantageously integrated into existing Government owned facilities. There are, at present, no Government owned forging facilities suitable for the contemplated operations because the Ordnance has been primarily concerned with armor casting facilities for the manufacture of tank components.

The Government owned Armorcast plant in Birdsboro, Pennsylvania, operated by a subsidiary of Birdsboro Steel Foundry and Machine Company, has been selected for this portion of the study. The attached drawing #1517 "Plant Layout--Forging Plant for Tank--Hull Fronts; Birdsboro Armorcast" shows the addition to this Government facility of plant space and equipment comprising die forging facilities.

Serial # 33

As originally constituted, the Birdsboro Armorcast foundry had the capacity to produce approximately 3,500 tons of cast armor per month, or, in terms of the quantity of items, to produce about 150 standard one piece (M-48) hulls and an equal number of turrets in accordance with the original M-48 design. This is a considerably smaller casting capacity than is required to suit the forging facility. The capacity of the Birdsboro armor casting installation could be substantially increased. In March 1958, Birdsboro Steel Foundry and Machine Company completed a report of an engineering study for the expansion of cast armor facilities which was submitted to the Philadelphia Ordnance District. This report discussed the feasibility of increasing the facilities of the foundry to approximately 7,000 tons per month of armor castings.

The main limitation of the Birdsboro facility (as with virtually all foundries) is not the melting capacity but the limited size of the casting floor. As a matter of fact, the current melting and pouring capacity of the Birdsboro plant is at least 12,000 tons and possibly 15,000 tons monthly, or approximately 3-1/2 times the current possible output of 3,500 tons of cast hulls and turrets. The modified plant suggested by Birdsboro would have a melting capacity of 20,000 tons possibly 25,000 tons monthly, but would produce only 7,000 tons of castings monthly.

Consequently, the Birdsboro facility, even in its present condition, could supply practically the entire ingot demand of the forging plant. Admittedly, no turrets could be cast in Birdsboro under those conditions, however, considering that all hull noses would be pulled out of other foundries, sufficient additional turret casting capacity would become automatically available.

We feel therefore, that the elimination of turret casting at Birdsboro will in no way aggravate the situation; on the contrary, it will improve the overall logistical planning.

Serial # 33

Referring again to our drawing #1517, we show how a forge plant can be appended to the existing Birdsboro armor cast foundry, the extent of the installation not exceeding the area available between the casting plant and the natural obstacles to expansion. As shown in this layout, the area covered by the forging section of this installation is approximately 373,800 square feet which is about 6-1/2% larger than the layout of the forge plant shown on drawing #1498. The increase in size is brought about by the necessity for arranging the various elements of the plant somewhat differently from the layout shown on drawing #1498. In spite of the limitation imposed on the planning by the selection of this particular Government owned facility, the building of forging plant facilities at Birdsboro is feasible.

G. Integration with a Government Owned Heavy Forging Facility

The Government owned facility at North Grafton, Massachusetts, has been selected as the base although in its present state this facility is not suited for the production of the nose forgings required by the current designs. Nevertheless, considering all the aspects of locating the proposed forging installation at this site, one inevitably comes to the conclusion that advantages far outweigh the disadvantages:

a) The number of American personnel available to operate a plant for the production of forgings in closed dies in connection with a hydraulic press is very limited. The experience gained to date is confined almost exclusively to the production of forgings in light metals. This is done on a considerable scale by Wyman-Gordon in North Grafton, Massachusetts, by Alcoa in Cleveland, Ohio, by Bridgeport Brass Company in Adrian, Michigan, by Kaiser Aluminum in Erie, Pennsylvania, by Harvey Machine Company in Torrence, California, and by a few others.

G. Integration with a Government Owned Heavy Forging Facility

The Government owned facility at North Grafton, Massachusetts, has been selected as the base although in its present state this facility is not suited for the production of the nose forgings required by the current designs. Nevertheless, considering all the aspects of locating the proposed forging installation at this site, one inevitably comes to the conclusion that advantages far outweigh the disadvantages:

a) The number of American personnel available to operate a plant for the production of forgings in closed dies in connection with a hydraulic press is very limited. The experience gained to date is confined almost exclusively to the production of forgings in light metals. This is done on a considerable scale by Wyman-Gordon in North Grafton, Massachusetts, by Alcoa in Cleveland, Ohio, by Bridgeport Brass Company in Adrian, Michigan, by Kaiser Aluminum in Erie, Pennsylvania, by Harvey Machine Company in Torrence, California, and by a few others.

Of the above plants only that operated by Wyman-Gordon has experience in forging of ferrous metals. The only other plant with this type of experience would be Cameron Iron Works in Houston, Texas. (Plants of Ladish, Kropp, Taylor operate hammers, not presses).

b. The Government owned, Wyman-Gordon operated, plant at North Grafton, Massachusetts, is equipped with presses as large as 50,000 tons and includes machines of 35,000 tons, 18,000 tons, 7,700 tons, etc. Consequently, the Grafton personnel will be familiar with the operation of large presses.

c. The extensive die-making facilities at this Air Force owned plant lend themselves, with very little change or addition, to the manufacture of the dies required for the production of tank noses and other items of ordnance equipment. The machine tools required for the outfitting of a new die shop installation would require the expenditure of substantial amounts of money, and another installation similar to the one in existence would burden the Government with an excess of large die-making capacity. Considering the die requirement of the production of forged tank hull noses, it should be noted that this production will not require great quantities of dies, nor dies which are complex in shape or in size. These, however, will require the attentions and the workmanship of skilled die-makers. In this respect, the die-making facility now in operation at the Wyman-Gordon plant could be used with very little change, addition, or modification to provide the dies required.

d. The new forging facility will be sufficiently versatile to be used in peace time for the production of various forged items other than those required by the Ordnance in times of emergency (tank noses and/or other tank elements). Since this practice will require the use of dies of a large variety, although not of a great number, it is deemed advisable that the die shop of this existing installation be used.

e. The production situation with regard to the forging of tank noses will in most respects exactly parallel that found to exist in the production of elements of manned aircraft. A comparatively short period of intense production requirement during emergencies is followed by an extended period of relaxed government and military needs. Since the economy of press operation will dictate that this installation produce on a more or less continuous basis, the requirement for an efficient press operating organization with research and sales facilities, in addition to operating techniques, etc., will indicate the selection of the operator. Since it is not the purpose of this report to suggest or recommend a particular press operator, this statement above is made with the interest of the Government in mind.

f. Responsible representatives of the Air Force have stated repeatedly that they are prepared to make arrangements with the Chief of Ordnance assuring the Ordnance of the availability of the Air Force owned portion of the installation for Ordnance needs during an emergency. Such arrangements could go so far as to transfer the cognizance of the plant to the Chief of Ordnance.

Serial # 32

g. Referring again to drawing #1500, it should be noted that the new forging installation can be added to the existing Air Force owned plant in such a way that the main press bay will be a continuation of the present large press bay of the referenced installation. In all other respects, the layout shown in drawing #1500 is identical with that shown on our drawing #1498. It is not contemplated to alter any of the physical aspects of the existing Wyman-Gordon plant by the installation of the new tank hull nose forging facility.

XV - SPECIFICATIONS OF MAJOR ITEMS OF EQUIPMENT

A. Presses

1. Closed Die Forging Press - 75,000 Tons Capacity

This press is described in detail elsewhere in this report.

a. Performance Specifications:

Rated capacity..........	75,000 tons at 1,000 psi steplessly adjustable pressure ranges.
Stroke.................	6'6"
Daylight................	18'
Table size..............	13' x 13'
Forging speed...........	72" per minute, steplessly adjustable
Rapid advance...........	480" per minute
Return speed............	480" per minute
Sliding table...........	movable to one side of press
Stroke of table shift..............	20' to clear the press, so as to make possible the removal of the die sets using the overhead crane
Maximum eccentric load at maximum capacity....	24" diameter circle
Ejector arrangement:	to make possible the removal of work piece from the die
Speed of table shift......	480" per minute

b. Design Specifications

Main hydraulic system pressure (maximum)	10,000 psi (intensified)
Pressure source.........................	pressurized water, with 1-1/2% rust preventative added
Pressure water generation...............	Plunger pumps
Pump capacity...........................	7,500 HP
Accumulator type........................	hydro-pneumatic
Accumulator pressure (maximum)..........	5,000 psi
Accumulator pressure (minimum)..........	4,500 psi
Intensification.........................	2:1
Intensifier.............................	multiple ram type (three rams)
Total accumulator volume................	12,000 cubic feet
Main Press actuating system.............	single cylinder
Return system...........................	four return cylinders 2,000 tons capacity each
Height: above floor.....................	25 feet
Height: below floor.....................	20 feet
Total weight............................	3,000 tons
Weight of moving parts..................	1,000 tons
Space requirement of press proper including table shift.....................	25' x 50'

2. Pre Forging Press

The pre forging press is water hydraulic vertical down-acting type, consisting of three (3) inserted main cylinders, crown, four (4) steel columns, moving platen and an extra rigid base. The press is to be operated by a water hydraulic accumulator and pump station described elsewhere in this specification. The three cylinder arrangement will permit three (3) stage operation of the main slide. Some of the detailed specifications for this equipment are as follows: -

Maximum capacity of press	8,000 tons
Stroke of the main slide	60 inches
The daylight	108 inches
Size of the bolsters	left to right- 96 inches
Size of the bolsters	front to back- 72 inches
Gross capacity of return cylinders	500 tons
Capacity of main ram	5,000 tons
Capacity of two (2) side rams	1,500 tons, each
Maximum eccentricity at maximum capacity	12 inches diam. circle

The operating speeds are as follows:

Main slide, rapid closing....600 inches per minute

Main slide pressing stroke

at 8,000 tons......0 to 60 inches per minute

at 5,000 tons......0 to 90 inches per minute

at 3,000 tons......0 to 180 inches per minute

Rapid return,
maximum speed.............600 inches per minute

Number of cogging
strokes per minute..........15 at 4 inches penetration

3. Trimming Press

During the closed die forging operation an extension of metal is extruded beyond the length of hull required. The trimming of the work piece is accomplished while the forging is at an elevated temperature. The work piece is located on a mandrel with its long axis horizontal. The upper trim die is machined in accordance with the edge contour required of the finished piece and, when brought to the maximum downward stroke, shears off the excess metal on one half of the forging. Reversing the forging position permits shearing of the excess on the other half of the forging.

The press is water hydraulic operated, vertical, down-acting type, and consists of a single inserted steel main cylinder, top head casting, down-acting main ram, a cast steel moving pattern and an extra rigid base casting. The frame may be of the side housing type construction or of the open four (4) column type. The press is operated by the water hydraulic accumulator and pumping station described elsewhere in this report.

The detailed specifications are as follows:

Maximum capacity of press.... 3,000 tons at 5,000 psi

Stroke of the main slide....... 60 inches

Daylight.................... 96 inches

Maximum eccentric loading... 12 inches

Size of the bolsters:

left to right........ 120 inches

front to back....... 102 inches

The operating speeds of the press are as follows:

Main slide, rapid advance	600 inches per minute
Main slide, pressing	180 inches per minute
Main slide, return	600 inches per minute
Hydraulic operating pressure	maximum: 5,000 psi minimum: 4,500 psi

4. Forge Straightening Press

After the drawing operation it may be necessary to remove distortion or warpage which has not been alleviated during the heat treating process. This is accomplished by means of a forge straightening press, specially adapted for the straightening of the forging to be produced. The straightening must be precisely performed to provide the accuracy of final dimensions consistent with the item to be produced. Slow pressing speed and positive control of stroke are necessary in such a procedure, hence, an oil hydraulic press is indicated.

An oil hydraulic press with its lower fluid velocity and slow press motions satisfies these requirements with a simple pump volume control arrangement. A similar control for speed applied to a water hydraulic press requires the addition of complex and sophisticated valving.

The specifications for the forge straightening press are as follows:

Maximum of capacity of press....	1,000 tons at 2,500 psi working pressure
Actuating medium..............	direct connected hydraulic oil pumps
Right to left between tie rods....	144 inches
Maximum width of base, front to back.........	76 inches
Stroke of press	30 inches
Standard daylight..............	84 inches
Minimum pressing speed.......	6 inches per minute
Rapid closing speed of press..........	720 inches per minute
Rapid return speed of press..........	adjustable to 720 inches per minute

The type of speed control is to be the manually adjustable variable delivery pump(s).

B. Heating Equipment

1. Melting Furnace

Based on the estimated ultimate production of 100,000 pounds per hour of billets, we have selected for the layouts providing for new melting capacity the following melting furnaces:

> Three (3) 125 ton capacity, top charging, electric furnaces, each with an approximate outer shell diameter of 21 feet.

The cylindrical furnace shell is built of heavy steel plate; the inverted arch anchored bottom and the arched, water cooled refractory roof, form a spherical shell with a minimum of surface area, keeping the radiation losses low. The furnaces are of the top charging type, with hydraulically operated swing type roofs. Heavy bezel rings attached to the shell form a support for the roof when the furnace is in operation. The rings are water cooled to prevent distortion. This ring has positioning pins to properly align the roof, insuring complete closure.

The furnaces tilt on steel rocker plates attached at the bottom of the furnace shell. The furnace is tilted by means of two (2) heavy steel hydraulic cylinders on either side. The maximum tilt for pouring is 45° and approximately 20° in the opposite direction is allowed for slagging. Controlled from a central console are the furnace tilting, roof removal, loading and unloading door operation, electrode lowering and other operations. The electrodes are raised or lowered by servo-motor operated winches mounted directly to the furnace shell. The electrode arms are mechanically operated and are water cooled.

The electrode arms are fastened to the electrode columns which are guided in hardened roller bearings to provide suitable and easy adjustment. The carbon electrodes are held in a triangular formation concentrating the heat and are retained in holder brackets by heavy springs.

The charging or furnace door is heavily reinforced with a steel yoke and is water-jacketed for cooling purposes. All doors are electrically opened and closed from remote points.

The removable roof is supported on outrigger arms rigidly attached to the furnace proper by the roof ring, by a quick-connecting adjustable linkage arrangement. Locating pins on the ring position the roof accurately.

2. Billet Heating Furnace

Of the various types of billet heating furnaces investigated, we feel the rotary hearth type, gas fired furnace would best fit the requirements of this case.

The furnaces may be used for other than ordnance work at various times, and, it is improbable that the size of billet will be consistent. In truth, the furnaces may be required to handle a wide variety of shapes, sizes and metals.

Rotary hearth furnaces are best suited to the conditions imposed here. Inasmuch as there may be no pouring facilities integral with the forge plant, billets would be transported in by rail or other means. This would mean that the furnaces would have to completely heat cold billets to forging temperature in the shortest possible time.

Rotary hearth furnaces require a minimum of maintenance work. Beside the replacement of lining and curb brick, little work and expense are required.

Other advantages of Rotary furnaces are their low scale loss, peak output in terms of manpower employed, ease of billet loading and unloading.

Based on the specified 100,000#/hr. we recommend three (3) Billet Heating Rotary Hearth Furnaces.

This furnace will be able to heat ten (10) billets at 10,000 pounds per hour. The total capacity of each furnace will be 35 billets. Billets will be discharged at the rate of one every 6 minutes.

The Furnace description follows:

Hearth diameter will be approximately 45 feet. Outside diameter will be approximately 50 feet.

Furnace will be doughnut shaped for efficient heating. Roof will be sprung arch type. Hearth alignment will be maintained by a centering device to keep the hearth concentric with the furnace wall. Expansion differentials are compensated for without causing distortion of any part of the hearth or its supports by segmented sections independently supported. Bottom seals prevent the escape of heat or infiltration of air through the botton of the furnace.

Temperature variations in the rotary furnace are controlled to a narroe margin. The burners are designed for either gas or oil. They operate in independent groups arranged in the required number of zones and are set radially in the furnace walls, with one or more burners provided between charging and discharging doors. Burners are located on both the inside and outside walls. Each zone is supplied with a controlled amount of fuel so that operation affords ample flexibility to permit heating of any type, shape or grade of metal required.

Furnaces are equipped with automatic combustion, pressure and temperature controls. These permit variations in combustion characteristics, ranging from a highly reducing, to neutral, to highly oxidizing mixtures. The automatic temperature and pressure control assure uniform heating of the work and eliminate temperature gradients within the furnace chamber.

All waste gases leave the furnace through flues located at hearth level. Access to these flues is through the walls at the entering end of each zine to effect complete utilization of the hot gas counterflowing the work before leaving the furnace chamber. Each flue is equipped with an automatically controlled pressure damper.

Another notable feature of the rotary hearth furnace is the use of end piers on the furnace hearth. These piers lift the billet from the hearth to allow a more uniform and rapid heating.

Improved baffle designs insure definite and accurate zoning. Light refractories or insulating firebrick are to be used in the roof and floor of the furnace. In addition, the rotary furnace can hold full capacity charges for extended periods of time far exceeding the normal complete heating time. This is required if press or other equipment downtime causes production interruptions. The furnace must be able to be emptied without charging additional material.

3. Billet Reheating Furnace

Two (2) double reheat furnaces will be sufficient to maintain the production goal of 3300 units per month.

The capacity of the two reheat furnaces will be adequate to compensate for heat lost during the pre forging operation and the loss during the usual minor delays in forging and billet transport time. Excessive reheats or bottlenecks in forging sequences would require additional furnace facilities.

Reheat furnaces of the type selected guarantee appropriate temperatures for forging and insure even distribution of heat in the preform before the final forging. These furnaces will be 22 feet wide by 14 feet deep with two half doors on the 22 foot side facing the working area. Charging machines will handle billets from the delivery buggy, the reheating furnace or the forging manipulator. Furnaces will operate on the same fuels as the rotary hearth billet furnaces with controlled fuel-air ratios, temperature and pressure controls and other features of automatic control.

XVI - CHECK LIST OF EQUIPMENT FOR SOME OF THE AUXILIARY DEPARTMENTS

This section represents a draft of a checklist for the equipment to be installed in various auxiliary departments.

The checklist should not be considered as complete and final. The purpose of including this list into the report is to preserve work already done as reference for possible continuation of the project.

XVI - CHECK LIST OF EQUIPMENT FOR SOME OF THE AUXILIARY DEPARTMENTS

A. Die Manufacturing

Tools large enough to handle 167,000 lb. ingot 75" x 123" x 80":

1. Planers
2. Milling Machinery
3. Boring Mill
4. Radial Drills
5. Die Sinkers (automatic & hand operated)
6. Hand Grinders w/exhausts
7. Surface Plates
8. Template storage, layout and fabrication (Wood Shop for Models)
9. Quench Tank
10. Hardening Furnace

B. Maintenance

1. Lubrication storage & equipment (portable)
2. Plumbing storage and machinery
3. Electricians
4. Welding equipment (portable and fixed)
5. Grinding machinery (surface and tool)
6. Saws (band, tilting and/or DoAll)
7. Drills (radial, etc.)
8. Milling machinery
9. Boring mills
10. Lathes
11. Presses (hydraulic, arbor, brake)
12. Surface plates
13. Tool room
14. Tool room machinery (precision lathes, grinders, small milling machine, drill press, saws.
15. Oxygen and acetylene supplies
16. Maintenance tool crib (small tools)

C. Laboratory Testing

1. Testing Machinery

   a. universal testing machinery (mech.)
   b. " " " (hyd.)
   c. potentiometer
   d. creep test machinery
   e. stress rupture machinery
   f. minell test machinery

2. Machine Shop

a.	surface grinder)	
b.	lathes)	
c.	comparator)	
d.	drill presses)	General Tools
e.	shaper)	
f.	saws)	
g.	grinders)	

3. Heat Treat

   a. homogenizing furnace
   b. salt bath furnace
   c. electric furnace
   d. atmosphere generator
   e. aging oven
   f. vapor degreaser
   g. oil quench tank, water quench tank

4. Instrument Room

   a. oscilloscope
   b. calibrating equipment
   c. photo laboratory

D. Administration

1. General Offices
2. Locker, Wash, Rest Rooms
3. Safety and First Aid
4. General Stores
5. Engineering
6. Shop Offices
7. Janitorial

E. Inspection

1. Surface plates and measuring instruments
2. Reflectoscope
3. Immerscope tanks
4. Magnaflux equipment

XVII - INFORMATION ON BASIC DESIGN DATA AND WORKING PAPERS

I - Closed Die Forging Press Capacity

A. Specific Forging Pressure — 40,000 psi

This value is adopted based on the experience gained in the production of closed die forgings of smaller size. Considered in this value also is the back extrusion of steel billet in the last stages of the forging operation.

Serial # 8

B. Area of Required Section (See our drawing 70-1164) — 3,265 sq. in.

The capacity required in tons:

$$\frac{(40{,}000)\ (3{,}265)}{2{,}000} = 65{,}300 \text{ tons}$$

Allowance: excess capacity for non-homogeneous material, uneven heating of billet and dies - 10%

65,300 x 1.1 = 72,830 tons

Nominal rating of press = 75,000 tons.

II - Water Power Station

A single accumulator station to service the major items of water hydraulic press equipment is proposed. The single station shows economies in initial cost due to the diversification factor which varies between 95% and 60%, depending on the size and number of different items of equipment operating from the station and the duty cycle and usage of the component parts.

The capacity requirements are tabulated and computed in Table I.

XVII

TABLE I

ACCUMULATOR STATION

Press Capacity	A Piston Area	B Stroke	C Vol/Stroke in^3	D Total Vol. per Stroke	E Stroke/Min	F Pump Volume Cubic Feet per Hour
75,000 Tons	33,340 sq. in.	78"	2,600,520	1890 cu. ft.	20	37,800
8,000 Tons	3,560 sq. in.	60"	213,600	154 cu. ft.	20	3,080
3,000 Tons	1,340 sq. in.	60"	80,400	59 cu. ft.	40	2,360
				2103 cu. ft.		43,240 cu. ft. per hr.

Accumulator Volume

Gross requirement (bottle capacity) = (2103) (8) = 16,824 cu. ft.

Diversification factor - 80% = 13,300 cubic feet, air and water capacity.

Pump Capacity

Convert capacity into gallons per minute $\frac{(43,240)\ (1728)}{(60)\ (231)} = 5391$

$= 5400$ gallons/minute

Pump Motor Capacity

5400 gallons per minute could be supplied with installed motor capacity of 7500 HP.

XVIII - OPERATIONAL ANALYSIS OF THE ISOLATED FORGING PLANT

#	Operation	Personnel Classification
10	Receiving	Foreman Receiving clerk Crane operators Helpers
20	Receiving Inspection	Inspectors
30	Storage	Crane operators Helpers
40	Weighing	Scale operator Fork truck drivers Helpers
45	Cutting	Saw operator Helpers
50	Storing	Fork truck drivers Helpers
60	Heating (Rotary Furnaces)	Foreman Furnace Operator Manipulator Operator Helpers
70	Transport	Billet handlers (fork truck or manipulator) Helpers
75	Blanking (8000 ton press)	Foreman Press operator Manipulator operator Helpers
80	Transport	Billet handlers Helpers
85	Reheating (reheating furnaces)	Foreman Furnace operator Helpers

#	Operation	Personnel Classification
90	Transport	Billet handlers Helpers
95	Closed-die Forging (75,000 ton press)	Foreman Press operator Manipulator operator
100	Transport	Forging handlers Helpers
105	Trimming (3,000 ton press)	Foreman Press operator Manipulator operator Helpers
110	Sandblasting	Foreman Fork truck operators Helpers
120	Inspection	Inspectors Helpers
130	Straightening (1,000 ton press)	Foreman Press operator Crane operator Manipulator operator Helpers
140	Repairing (welding, cutting, chipping)	Foreman Welders Burners Chippers Helpers
150	Heat Treating	Foreman Equipment operators Helpers
155	Cleaning	Foreman Helpers

#	Operation	Personnel Classification
160	Inspection	Inspectors Helpers
170	Storage	Foreman Fork truck drivers Helpers
180	Shipping	Shipping clerk Crane operator Markers Helpers

SECTION V

BUDGETARY ESTIMATES

XIX - BUDGETARY ESTIMATES OF FIRST COST

Budgetary estimates of first cost are summarized on page 19.01.

The estimate is broken down into two parts:

Land and Buildings on pages 19.02 - 19.04

Equipment on pages 19.05 through 19.07

Land acquisition cost and all elements of land improvement cost are educated guesses rather than estimates because these costs greatly depend on site to be selected.

Building costs are also an uncertain item. However, estimated cost per square foot represent reasonable average figures.

With regard to main items of equipment (incl. cranes) we would like to point out that all cost estimates are based on data obtained from qualified manufacturers. This statement includes the accumulator station Item B-1 page 19.05. It does not cover the estimated cost of the 75,000 ton press. However, the pound price of this piece of equipment has been assumed with substantially over $1.- while press prices in general run around $.60-.80 per pound.

Summarizing, we can say that a special effort has been made to prepare this cost estimate along conservative lines. (See also contingencies on page 19.01 in the amount of 10% of estimated cost).

XIX - BUDGETARY ESTIMATES

BUDGETARY ESTIMATE OF FIRST COST

I	Construction Cost (land, buildings, cranes)	7,595,000
II	Equipment, installed	26,443,000
		34,038,000
III	Engineering and Management of Construction	3,404,000
IV	Contingencies	3,404,000
		40,846,000

XIX - BUDGETARY ESTIMATES

BUDGETARY ESTIMATE OF BUILDING COST

1. Land: approximate building area, including auxiliary areas --- 10 acres

   Land required: estimated 10 x building area = 100 acres

   Land cost for isolated plant "guesstimated" at $500 per acre — $ 50,000

2. Land Improvement: ("guesstimated" amounts)

Grading, $1,000 per acre	100,000.-
Railroad	200,000.-
Roads and parking lot (400 cars x 25 sq. yds per car x $10.)	100,000.-
Water supply	200,000.-
Sewers and drainage	100,000.-
Main gas line	25,000.-
Plant protection	50,000.-
Landscaping	50,000.-
	825,000.-

XIX - BUDGETARY ESTIMATES

BUILDING COST

3. Buildings: Estimate based on layout drawing 1498.

a) Main building:

High bay for presses 84' x 825' = 69,400 = 70,000 sq.ft. at $20 per sq. ft.	1,400,000.-
Low bays 336 x 825' = 277,000 sq. ft. at $15.	4,150,000.-
Total Cost of Main Building.................	5,550,000.-

b) Auxiliary areas:

Substation	2,500 sq.ft.	40,000
Laboratory	8,500 sq.ft.	170,000
First Aid	1,500 sq.ft.	30,000
Cafeteria	5,000 sq.ft.	100,000
Garage	7,500 sq.ft.	75,000
Miscellaneous	15,000 sq.ft.	300,000
		715,000

Personnel lockers:
30 sq.ft. per person for a
total of 400 persons:
12,000 sq.ft. at $15. 180,000

Total Auxiliary Buildings.................... 895,000.-

XIX - BUDGETARY ESTIMATES

4. Cranes (all main cranes for 84' wide bays):

Receiving bay	5 cranes	30/10
Furnace charging bay	1 "	15/5
Furnace discharge bay	3 "	15/5
" " "	2 "	30/10
Press bay	1 "	100/25
" "	1 "	50/15
" "	2 "	15/5
Accumulator bay	2 "	15/5
" "	1 "	20

Total

1 crane	100/25	175,000.-	
1 crane	50/15	115,000.-	
7 cranes	30/10	490,000.-	
1 crane	20	40,000.-	
8 cranes	15/5	280,000.-	1,100,000.-

5. Total Cost of Construction, Land, Building and Cranes.............................. 7,595,000.-

XIX

BUDGETARY ESTIMATE OF EQUIPMENT COST

Forge Shop	Rating	Quantity	Cost of Equipment	Installation	Total
A. Presses					
1. Forging Press	75,000 ton	1	$8,580,000	$2,193,000	$10,773,000
2. " "	8,000 ton	1	925,000	231,000	1,156,000
3. Trimming Press	3,000 ton	1	370,000	92,500	462,500
4. Straightening	1,500 ton	1	97,000	24,000	121,000
					$12,512,500
B. Auxiliaries for Presses					
1. Accumulator Station	7,500 HP 10,000 cub. ft.		$4,528,000	$1,132,000	$ 5,660,000
2. Die Sets			1,210,000	----	1,210,000
					$ 6,870,000
C. Furnaces					
1. Rotary Hearth and	15 ton/hr.	3	$1,205,000	$ 301,000	$ 1,506,000
2. Reheating Furnaces		2			
3. Heat Treating Furnaces		3	890,000	222,500	1,112,500
					$ 2,618,500
				Transfer Total	$22,000,000

XIX

BUDGETARY ESTIMATE OF EQUIPMENT COST

Forge Shop	Rating	Quantity	Cost of Equipment	Installation	Total
			Transfer Total		$22,000,000
D. Material Handling					
1. Floor type furnace charger		1	$ 179,000	----	179,000
2. Fork lift trucks		15	176,000	----	176,000
3. Handling and storage equipment			275,000	69,000	344,000
4. Weighing equipment			17,000	4,000	21,000
5. Conveyors in the forge shop arca			240,000	60,000	300,000
					$ 1,020,000
E. Miscelanneous Equipment					
1. Ingot saws			$ 215,000	54,000	$ 269,000
2. Welding and cutting tools			120,000	----	120,000
3. Miscellaneous small tools			50,000	----	50,000
4. Sandblasting			150,000	34,000	184,000
					$ 623,000
			Transfer Total		$23,643,000

XIX

BUDGETARY ESTIMATE OF EQUIPMENT COST

Forge Shop	Rating	Quantity	Cost of Equipment	Installation	Total
			Transfer Total		$23,643,000
F. Service Equipment					
Oxygen distribution system					$ 50,000
Substation					600,000
Water supply and sewage					600,000
Steam, Air Gas Systems					300,000
Repair and Maintenance Shop					600,000
Shipping and Receiving					100,000
Laboratory					200,000
Office					125,000
Cafeteria					200,000
First Aid					25,000
					$ 2,800,000
			TOTAL EQUIPMENT		$26,443,000

XX - ESTIMATE OF OPERATING EXPENSE

The manning tables (pages 20.01-20.05) are divided into salaried and hourly employees.

Salaried employees have been estimated for a separate plant as well as for a plant combined with an already existing one. The payroll savings shown are rather substantial.

The manning tables for hourly employees are estimated on the basis of the operational sequence shown in part XVIII. A substantial number of "unassigned" personnel has been added to cover loopholes, tight spots, etc.

Maintenance figures (page 20.14) represent good commercial practice.

Depreciation figures are shown, however, it is realized that the U. S. Government does not keep its books in accordance with the double entry system. The U. S. Government books are set up in accordance with the so-called "cameralistic" system and therefore do not show depreciation.

Still, in order to allow a comparison with commercial operation, pertinent costs are shown both ways: with and without depreciation.

Miscellaneous expense for supplies is based, in general, on good commercial practice. The costs of the dies are dependent on the allowable tolerances which, in our case, are very wide and therefore favorable.

The cost of utilities are based on good commercial practice.

XX

MANNING TABLES AND PAYROLL ESTIMATES

I - Salaried Employees

	Isolated Plant			Plant Combined either with a Casting Plant or with a Forging Plant		
	Persons #	Average Annual Salary $	Total Annual Cost $	Av Persons #	Average Annual Salary $	Total Annual Cost $
A. Management						
General Manager	1	30,000	30,000	--	--	--
Assistant	1	12,000	12,000	1	12,000	12,000
Secretaries	2	5,000	10,000	1	4,000	4,000
	4		52,000	2		16,000

XX

	Isolated Plant			Plant Combined either with a Casting Plant or with a Forging Plant		
	Persons #	Average Annual Salary $	Total Annual Cost $	Persons #	Average Annual Salary $	Total Annual Cost $
B. Production Group						
B-1 Production						
Mgr. & Assts.	3	12,000	36,000	3	10,000	30,000
Clerical Help	3	4,000	12,000	3	4,000	12,000
	6		48,000	6		42,000
B-2 Quality Control						
Chief Inspector	1	10,000	10,000	--	--	--
Clerical Help	2	4,000	8,000	1	4,000	4,000
	3		18,000	1		4,000
B-3 Maintenance						
Chief of Maintenance & Assistants	3	9,000	27,000	--	--	--
Clerical Help	1	4,000	4,000	1	4,000	4,000
	4		31,000	1		4,000
B-4 Shipping, receiving Material handling.						
Traffic Manager	1	8,000	8,000	1	7,000	7,000
Manager of material handling & assts.	2	7,000	14,000	1	7,000	7,000
Clerical Help	2	4,000	8,000	1	4,000	4,000
	5		30,000	3		18,000
Total Group B:	18		127,000	11		68,000

XX

	Isolated Plant			Plant Combined with a Casting Plant or with a Forging Plant		
	Persons #	Average Annual Salary $	Total Annual Cost $	Persons #	Average Annual Salary $	Total Annual Cost $
C. Engineering Group						
C-1 Engineering Dept.						
Chief Engineer & Assts	3	13,000	39,000	3	11,000	33,000
Engineers	4	9,000	36,000	3	9,000	27,000
Draftsmen	8	7,500	60,000	8	7,500	60,000
Clerical Help	4	4,000	16,000	3	4,000	12,000
	19		151,000	17		132,000
C-2 Industrial Engineering						
Industrial Engineers	6	9,000	54,000	5	9,000	45,000
Time Study Men	2	7,500	15,000	2	7,500	15,000
Clerical Help	2	4,000	8,000	2	4,000	8,000
	10		77,000	9		68,000
C-3 Laboratory						
Chief Metallurgist & Assistants	3	12,000	36,000	3	11,000	33,000
Testing Staff	6	6,000	36,000	4	6,000	24,000
Clerical Help	3	4,000	12,000	3	4,000	12,000
	12		84,000	10		69,000
Total Group C:	41		312,000	36		269,000

XX

	Isolated Plant			Plant Combined with a Casting Plant or with a Forging Plant		
	Persons #	Average Annual Salary $	Total Annual Cost $	Persons #	Average Annual Salary $	Total Annual Cost $
D. Services						
D-1 Industrial Relations						
Personnel Manager & Assistant	2	10,000	20,000	1	8,000	8,000
Clerical Help	2	4,000	8,000	2	4,000	8,000
	4		28,000	3		16,000
D-2 Security						
Manager	1	8,000	8,000	-	--	--
Chief Guard	3	6,000	18,000	-	--	--
Guards	9	5,000	45,000	6	5,000	30,000
Clerical Help	1	4,000	4,000	1	4,000	4,000
	14		75,000	7		34,000
D-3 Safety & Health						
Safety Engineers	3	8,000	24,000	-	--	--
Clerical Help	3	4,000	12,000	2	4,000	8,000
Physician	1	12,000	12,000	1	6,000	6,000
Nurses	3	5,000	15,000	1	5,000	5,000
Clerical Help	2	4,000	8,000	1	4,000	4,000
	12		71,000	5		23,000

XX

	Isolated Plant			Plant Combined with a Casting Plant or with a Forging Plant		
	Persons #	Average Annual Salary $	Total Annual Cost $	Persons #	Average Annual Salary $	Total Annual Cost $
D-4 Accounting						
Accountants	3	9,000	27,000	3	8,000	24,000
Bookkeepers	6	7,500	45,000	4	7,500	30,000
Timekeepers	9	5,000	45,000	9	5,000	45,000
Clerks	6	5,500	33,000	4	5,500	22,000
Clerical Help	9	4,000	36,000	6	4,000	24,000
	33		186,000	26		145,000
D-5 Purchasing						
Purchasing Agent	1	8,000	8,000	1	6,000	6,000
Clerical Help	1	4,000	4,000	1	4,000	4,000
	2		12,000	2		10,000
Total Group D:	65		372,000	43		228,000
Total Salaried Payroll	128		863,000	92		581,000

XX

II - Hourly Employees

Operation	Area	Personnel	#Per Shift	Total #	Hourly Rate $
10	Receiving	Foreman	1	1	4.40
		Receiving clerk	1	1	2.50
		Crane operator	1	1	3.90
		Helpers	5	5	1.60
20	Receiving	Inspectors	2	2	2.50
30	Storage I	Crane operators	1	2	3.90
		Helpers	2	4	1.60
40	Weighing	Scale operator	1	2	2.50
		Fork truck drivers	2	4	2.00
		Helpers	1	2	1.60
45	Cutting	Saw operator	1	2	3.00
		Helpers	2	4	1.60
50	Storage II	Fork truck drivers	2	4	2.00
		Helpers	4	8	1.60
60	Rotary Furnaces	Foreman	1	2	4.40
		Furnace operator	1	3	2.50
		Manipulator operator	1	2	2.50
		Helpers	3	6	1.60

XX

II - Hourly Employees

Operation	Area	Personnel	#Per Shift	Total #	Hourly Rate $
70-75	Blanking press	Foreman	1	2	4.40
		Press operator	1	2	3.90
		Billet handlers	3	6	2.50
		Helpers	6	12	1.60
80-85	Reheating Furnaces	Foreman	1	2	4.40
		Furnace operator	1	3	2.50
		Helpers	3	6	1.60
90-95	Closed Die Forging Press	Foreman	1	2	4.40
		Press operator	1	2	3.90
		Billet handlers	3	6	2.50
		Helpers	8	16	1.60
100-105	Trimming Press	Foreman	1	2	4.40
		Press Operator	1	2	3.90
		Billet handlers	3	6	2.50
		Helpers	6	12	1.60
110	Sandblasting	Foreman	1	2	4.40
		Fork truck drivers	2	4	2.00
		Helpers	3	6	1.60

XX

II - Hourly Employees

Operation	Area	Personnel	#Per Shift	Total #	Hourly Rate $
120	Inspection	Inspectors	2	4	2.50
		Helpers	4	8	1.60
130	Straightening Press	Foreman	1	2	4.40
		Press operator	1	2	3.90
		Crane operator	1	2	3.90
		Manipulator operator	1	2	2.50
		Helpers	3	6	1.60
140	Repairing	Foreman	1	2	4.40
		Welders-Burners	10	30	2.50
		Chippers	5	15	2.00
		Crane operator	1	3	3.90
		Helpers	5	15	1.60
150-155	Heat Treating	Foreman	1	3	4.40
		Equipment operators	2	6	2.50
		Helpers	8	24	1.60
160	Inspection	Inspectors	2	5	2.50

XX

II - Hourly Employees

Operation	Area	Personnel	#Per Shift	Total #	Hourly Rate $
170	Storage III	Foreman	1	2	4.40
		Fork truck drivers	2	4	2.00
		Helpers	2	4	1.60
180	Shipping	Foreman	1	1	4.40
		Crane operator	2	2	3.90
		Shipping Clerk	1	1	2.50
		Fork truck drivers	2	2	2.00
		Markers	2	2	2.00
		Helpers	6	6	1.60

XX

II - Hourly Employees

Auxiliary Services	Personnel	#Per Shift	Total #	Hourly Rate $
Die Heating	Furnace operator	1	2	2.50
	Helpers	1	2	1.60
Accumulator Station	Foreman	1	2	4.40
	Helpers	1	2	1.60
Tool Crib	Stock Chasers	3	7	2.00
Unassigned	Crane operators	5	10	3.90
	Fork truck drivers	5	10	2.00
	Inspectors	5	10	2.50
	Manipulator operators	5	10	2.50
	Helpers	10	20	1.60
Maintenance	Class I		12	3.00
	Class II		12	2.50
	Class III		10	2.00
	Class IV		10	1.60

ENGINEERING SUP

SUMMARY OF HOURLY EMP

Operator #	Furnaces	Press Operator	Crane Operator	Saw Operator	Maint I	Insp. and Mrkrs	Ship. and Rec. Clks	Fur. and Heat Treat Optrs.	Ma Op an Bi Hn
10-20	1		1			2	1		
30			2						
40-45				1					
50									
60	2							3	
70-75	2	2							
80-85	2							3	
90-95	2	2							
100-105	2	2							
110	2								
120						4			
130	2	2	2						
140	3		3						
150-155	3							6	
160-170	2					5			
180	1		2			2	1		
Die Heat								2	
Accum. Sta	2								
Unass.			10			10			
Tool Crib									1[illegible]
Maint					12				
	26	8	20	1	12	23	2	14	3[illegible]
	26	28		13				115	
Rate	4.40	3.90		3.00				2.50	

1

LY EMPLOYEES

r. l at eat rs.	Manip. Optrs. and Billet Hndlrs	Wldrs and Brnrs	Maint II	Scale Oper-ators	Fork truck drvrs	Chprs	Stock Csrs	Maint III	Helpers	Maint IV
									5	
									4	
				2	4				6	
					4				8	
	2								6	
	6								12	
									6	
	6								16	
	6								12	
					4				6	
									8	
	2								6	
		30				15			15	
									24	
					4				4	
					2				6	
									2	
									2	
	10				10				20	
							7			
			12					10		10
	32	30	12	2	28	15	7	10	168	10
115					60				178	
2.50					2.00				1.60	

2

XX

PAYROLL FOR HOURLY EMPLOYEES

	#	Hourly Rate	Annual Payroll
Group I	26	4.40	237,952.-
Group II	28	3.90	227,136.-
Group III	13	3.00	81,120.-
Group IV	115	2.50	588,000.-
Group V	60	2.00	249,600.-
Group VI	178	1.60	592,384.-
			1,976,192.-

XX

SUMMARY

Total Salaried and Hourly Employees:

	Isolated Plant		Combination Plant	
	#	$	#	$
Hourly	420	1,976,000	420	1,976,000
Salaried	128	863,000	92	581,000
Total	548	2,839,000	512	2,557,000
Fringe Benefits	15%	425,850		383,550
Total		3,264,850		2,940,550

XX

SCHEDULE

MAINTENANCE AND DEPRECIATION

I Maintenance:

a)	Equipment:	4% on 27,765,000.-	1,110,600.-
b)	Buildings:	2% on 7,595,000.-	151,900.-
		Total Maintenance	1,262,500.-

II Depreciation (applicable to commercial operations only)

a)	Equipment:	6% on 29,167,000.-	1,750,020.-
b)	Buildings:	2-1/2% on 8,275,000.-	206,875.-
		Total Depreciation on 37,442,000.-	1,956,895.-

XX

SUMMARY OF MISCELLANEOUS OPERATING EXPENSES

A. **Supplies**

1.	General operating expenditures: Estimated at 20% of direct payroll		$ 395,000.-
2.	Die expenditures:		
	Original cost of one set of forging dies	700,000.	
	Die maintenance 10% of original cost after each 1,000 pieces		
	Estimated die life 10,000 pieces		
	Maintenance cost per 10,000 pieces	630,000.	
	Total die cost for 10,000 pieces	1,330,000.	
	Annual die cost based on 39,600 pieces		5,500,000.-
	Cost of auxiliary dies for small presses: 10% of main dies		550,000.-
3.	Small expendable tools, lubricants, miscellaneous items, etc.		395,000.-
	Total Cost of Supplies		$6,840,000.-

XX

B. Utilities

1. Water (nominal amount) $ 10,000.-

2. Electric power for the operation of presses:
Total theoretical rated power 30,000,000 kw.hr.
Use factor: .67
Cost: $.015 per kw.hr.
Total Cost: $30 \times 10^6 \times .67 \times .015$
(very conservative estimate) 300,000.-

3. Building heat: 200,000 sq.ft. x $.25 50,000.-

4. Industrial heat:

a) First estimate: $.001 per lb. for forge heating
$.005 per lb. for reheating and for each heating for heat treating
Total $.0025 per lb. x 400,000,000 lbs. 1,000,000.-

b) Second estimate:

Preheating for forging:	1000 Btu/lb.
Reheating for forging:	750 " "
Two heats for heat-treating	1250 Btu each
Total	3000 Btu per lb.

Cost of Gas: $.80 for 1000 cub. ft. (1,000,000 Btu)
Total Cost: $.80 \times 3000 \times 400 \times 10^6 \div 10^6 =$
= $960,000.-

5. Oxygen for welding and cutting 200,000.-

Total Cost of Utilities.......... $1,560,000.-

XXI - CONVERSION AND TOTAL COST

The sum total of operating expense including maintenance (and, as an alternative, also depreciation) represents the conversion cost.

Compared with a foundry operation, this cost is low. One must realize that the contemplated method of manufacturing does not require preparation of molds for each piece; nor does it require such extensive X-ray and magnaflux checks as are essential for the maintaining of quality of cast pieces.

The total cost of the workpiece aré favorably influenced by the use of cast billets: the amount ofhot work during the blanking and forging operations is sufficient to make cost billets acceptable.

XXI

ESTIMATED CONVERSION AND TOTAL COST OF THE FORGED NOSE FOR THE MAIN BATTLE TANK

A.	Personnel	3,265,000.-
B.	Maintenance	1,262,500.-
C.	Depreciation	1,956,895.-
D.	Supplies	6,840,000.-
E.	Utilities	1,560,000.-
	Total with Depreciation	14,884,395.-
	Total without Depreciation	12,927,500.-

Conversion cost per lb.

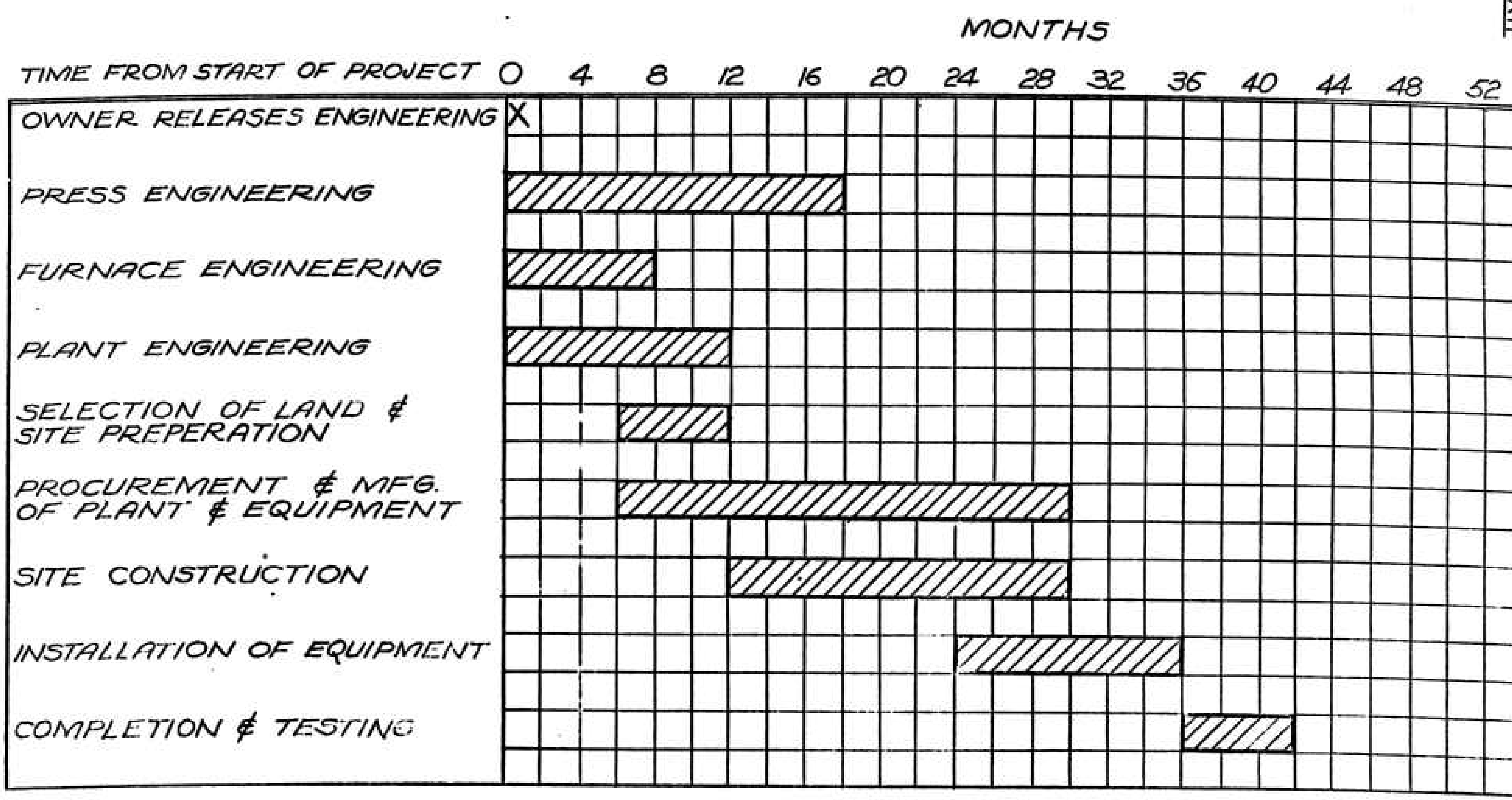
including depreciation	\$.038
without depreciation	\$.033

Cost of metal: \$.09 per lb.

Total cost of forging:

including depreciation	\$.128 per lb.
without depreciation	\$.123 per lb.

CONSTRUCTION TIMETABLE FOR A COMPLETE FACILITY



FOF VG OF NOSES
F THE MAIN
B TTLE TANK

SECTION VI

EVALUATION OF THE STUDY

XXIII - COST OF PROTOTYPES

As stated elsewhere in this report only the variant shown on drawing #70-1127* can be produced on the equipment available today.

This is not the currently produced model, nor is this the nose on which this report is based. For all that, it offers a satisfactory opportunity for proving out the project since the prototypes could be combined with the rest of some available hulls and subjected to extensive testing.

We would plan to produce the prototypes in the forging shop of Wyman-Gordon Company.

No furnaces large enough to preheat the billets are available in the Wyman-Gordon plant at present. We are confident that a furnace of proper size could be located in the Government surplus.

* Not included in this report.

Estimate of Cost:

	Large Furnace (six pieces heated simultaneously)		Small Furnace (one piece heated each time)
Engineering		25,000.-	
Tooling		150,000.-	
Forging cost for the lot of six	57,600.-		145,000.-
Cost of installing and removing a "G.f.E." furnace	60,000.-		30,000.-
Total Cost	292,600.--		350,000.--

Simultaneously, prototypes of front portions of wallplates could be produced. These prototypes would cost:

Cost of front upper and lower pieces (a lot of six)

Engineering	10,000.-
Tooling	11,640.-
Forging cost for the lot	9,320.-
Total Cost	30,960.-

Thus, total cost of the forged prototypes for the nose and for front portions of the side walls would be between

$324,000.- and $381,000.-

(depending on the size of a furnace available in Government surplus).

XXIV - SUMMARY AND EVALUATION

This summary and evaluation section recapitulates the main conclusions which are to be drawn from the work done in this study.

This section is divided into main sub-groups, discussing the topics as listed below.

A. Feasibility of Use of Equipment

B. Process Suitability

C. Objective Accomplishment

D. Tolerances

E. Costs

F. Peace Time Uses

G. Preferred Solution

A. As has been demonstrated in earlier portions of this report, the equipment necessary for the production of tank hull noses for the main battle tank is within the capability of the American industry.

Of prime concern in this consideration is the evaluation of the ability of the machine building industry in this country to produce the necessary forging equipment. The experience gained in the last dècade with the Air Force Heavy Press Program has demonstrated that a properly staffed and administered engineering organization can conceive, design, build, install, and place into operation the required facilities.

Another important item for this facility is the forging press proper. Our studies have revealed that this press can be built with less effort and less money than previously contemplated units of similar scope and size. Preliminary design

Serial # 2

work (see our drawing 12-1018) has indicated the extremely simple nature and structure of the press and installation. Basic considerations would require the application of principles and procedures well known today. The length, mass and weight of elements required for the press do not exceed reasonable sizes. Stress analytical investigation needed for the proportioning of sizes and shapes is simplified by the simple shape of all structural elements as well as work already done.

The specific requirements of the other major items of production equipment for the tank hull noses exhibit the same characteristics as do the requirements for the large press.

The other presses can be selected from among the standard items of supply and can be supplied on short delivery terms by a large number of press builders.

While the furnaces required are among the largest built, they will be designed and provided in accordance with well established principles of furnace design and construction.

As with the above items, the supply of the handling and conveying equipment for the progression of the hull nose forgings through the plant will be done by comparing the proposed handling system with standard items of supply of a large number of organizations active in this field.

B. Process Suitability

The study has demonstrated the practicality of the use of forgings to replace the conventional casting method for the production of tank hull noses.

While no forgings of the sizes described herein have as yet been produced, the work done in recent years has proven that the approach taken for the production of these large ordnance items is sound and within the present state of art.

C. Objective Accomplishment

We estimate that a forging installation such as herein described could be built in 3-1/2 years (see Part XXII).

We estimate that such a facility, once built and in operation on non-emergency items, could switch to hull nose production within seven days from the date of release. This fast switch would be predicated on existence of dies and on stock of ingots.

We estimate that under emergency conditions full production of tank hull noses could be achieved in forty five (45) days.

D. Tolerances

The most important aspect of dimensional tolerances of tank hull components is their influence on the weight of the vehicle.

It has been determined that a weight tolerance of ± of the hull nose weight will be acceptable from the operational viewpoint. It has been also determined that minus tolerances of local thicknesses are limited to - 7% while plus tolerances are limited by the total weight considerations only.

Forging die wear is in the direction of increasing the size of the produced part. The total weight of the forging produced tends to increase as the dies are used. This increase is particularly noticeable in certain areas of the die which are subject to constant wear erosion. The die design provisions, covered elsewhere in this report, discuss the work to be done in the reinforcement of the die, in the establishment of high wear locations, and in the supply of inserts in the die cavity and on the die punch to allow replacement of deteriorating parts.

It will be possible to hold the overall weight of the hull nose forging to within a tolerance of 7% over a range of 5,000 pieces or better, once a suitable method of control and die part replacement has been established.

The conventional closed die forging such as, for instance, used in the aircraft industry, is confronted with very narrow tolerances. In the case of the tank hull noses, the situation is quite different. We feel, therefore, that with the tolerance of 7% on the overall weight a run of 1,000 pieces between major die overhauls and a total die life of 10,000 pieces is feasible, provided proper die maintenance is taken care of.

E. Costs

As shown elsewhere in this report, the conversion cost per pound of steel as well as the overall cost of installation make a plant for the production of forged main battle tank elements an extremely competitive industrial installation.

Our cost figures are based on prices received within the last year. These have been tabulated and computed on a conservative basis to establish the ultimate costs. At the same time, the costs for the provision of similar items by the more conventional casting methods have also been determined, on the basis of other work done by this organization, during the last year. These reveal a cost per pound of casting hull in excess of 50-51 cents per pound. When considered from the additional points of view of the delivery required in the event of emergency, and from the point of view of cost of production, the attractiveness of the proposed method becomes pronounced.

F. Peace Time Use

Discussion of the peace time usefulness of the proposed facility involves examination of two aspects of the metal working field.

In the first instance, our present manufacturing economy shows there is a consistent and increasing demand for large closed die steel forgings. This demand for large forgings extends for example, into the need for high strength steel parts, for steel engine discs, for turbine and turbo-compressor rotors and blades, for vehicle side panels and floor plates, for wide forgings in steel and in other metals used in modern nuclear engines, for a large variety of automotive, aircraft and marine uses. These are fields in which the use of forgings has been restricted by the limitations placed on such production elements by the scope of available equipment and by limited understanding of the capability of the industry. The making available of the required equipment under the proposed program would help remove the limitations now in force. In this same category, we need mention the extensive field for large forgings in the manned aircraft industry, where ultra high strength elements are required for landing gear, structures, for aerodynamic foils and surfaces and for control equipment.

The proposed equipment can be used most effectively to provide circular forgings of configurations such as are required for space vehicle nose cones. Also with the further addition of the specialized tooling extremely large deep drawn parts with conventional two element dies as well as those formed on rubber pad extrusions can be produced. The concept of the proposed 75,000 ton press permits the production of all items and the application of all methods mentioned above.

A second area to be considered in the evaluation of the peace time uses of the facility described is in the realm of forging of metals now little used or as yet undiscovered.

Experience in the last decade has seen the development of a large variety of new structural materials. Such materials as, for example, beryllium, molybdenum, zirconium, titanium, etc. have in this period achieved the position of prime usefulness for the solution of many weight and strength problems in a large variety of items now being produced. Many of these materials cannot be produced in final shape by casting. Many can be used only after forging or extrusion processes that could be performed in the proposed facility.

Summarizing, one must say that the possibility of using the facility for steel forgings and for forgings in the newer materials assures the proposed installation of a sufficient work volume in peace time.

G. Preferred Solution

In the discussion above, describing the several alternatives for the building and location of the proposed installation, we have reviewed four possibilities. These were:

1. The isolated forging plant for tank hull fronts.
2. Combined casting and forging facilities for tank hull fronts.
3. A forging plant addition for tank hull fronts to be added to an existing foundry, like, for instance, to the Birdsboro Armorcast facility.
4. A plant for the production of tank hull fronts to be added to the present forging facility of the Wyman-Gordon Company.

In the opinion of the writers of this report, the proposed facility should be added to the Wyman-Gordon Company installation.

This suggestion is made in consideration of the following main points.

a) Required die making facilities have been installed and are in operation in this installation.

The cost for the production of a new die making facility could amount to a substantial addition to the capital cost of the installation.

b) The know-how and production technology associated with the operation of the massive indistrial equipment contemplated for this installation has been accumulating in Grafton for many years. This experience constitutes an important part of the ability to produce tank hull noses and other items of military necessity. It also assures of a proper use of the plant in peace time.

c) Wyman-Gordon, while serving as operator for the Government owned equipment in North Grafton, Mass., have for many years specialized in the production of forgings for the American industrial community, and have shown by their efforts in increasing the scope of their sales and of their products that they are continuously aware of the expanding market for their products. They have supplemented the Government furnished equipment by investing considerable funds in their own equipment. It would properly serve the best interests of the Government if the selected operator were to possess these important elements described above.

Final recommendations for the continuation of this study are presented in Part V of this report.

SECTION VII

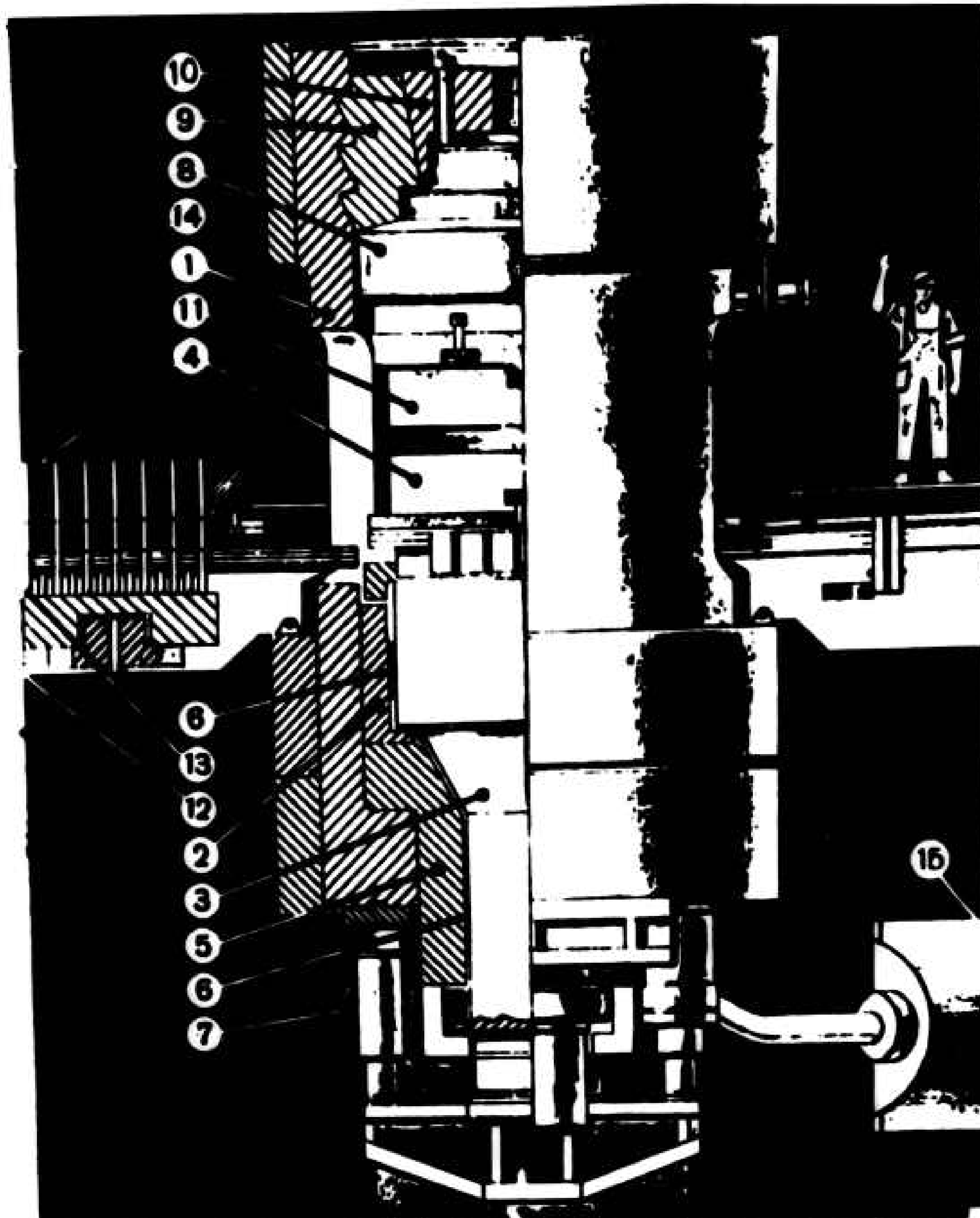
EXHIBITS AND DRAWINGS

Part

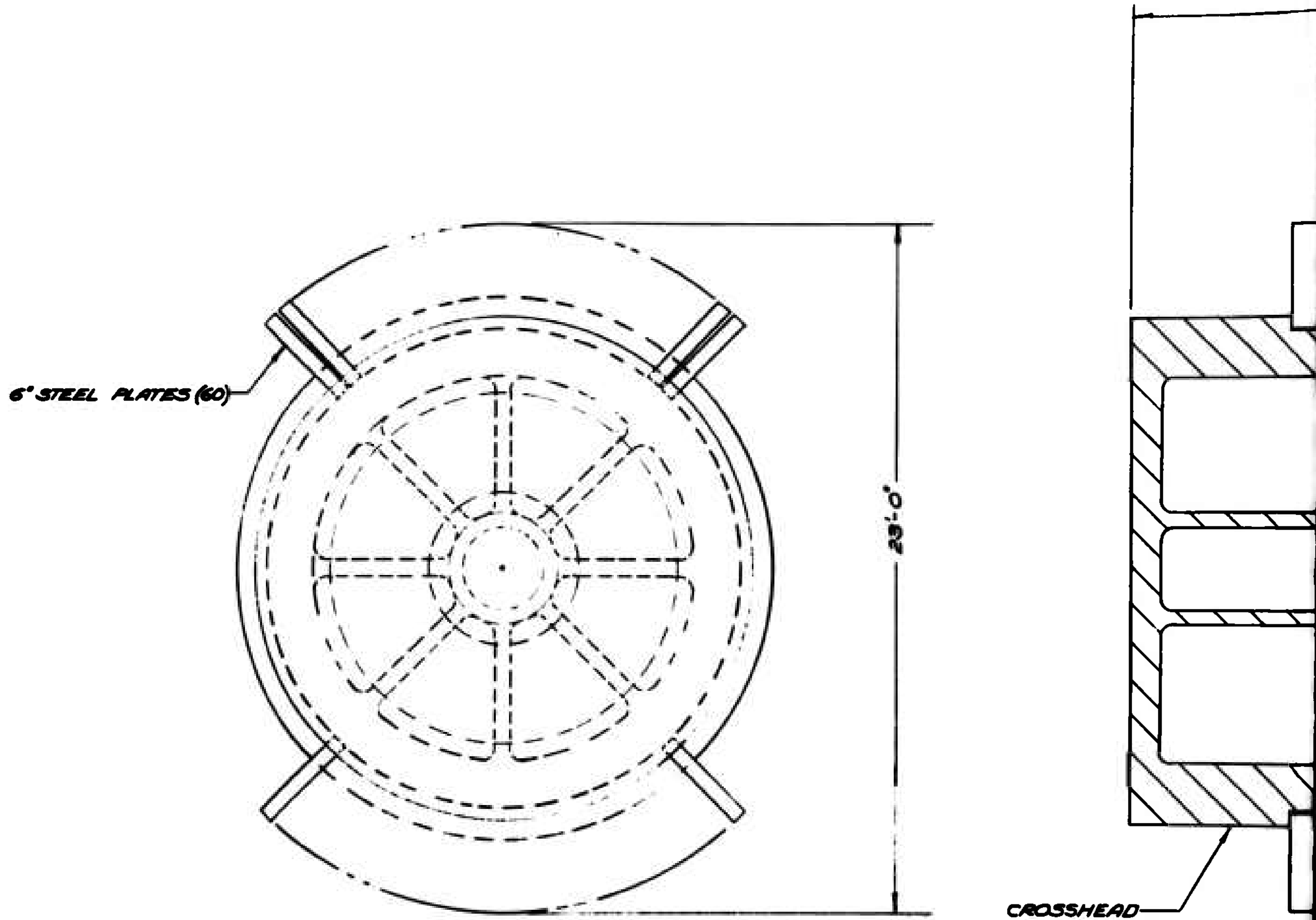
XXV Exhibits

A.

B.



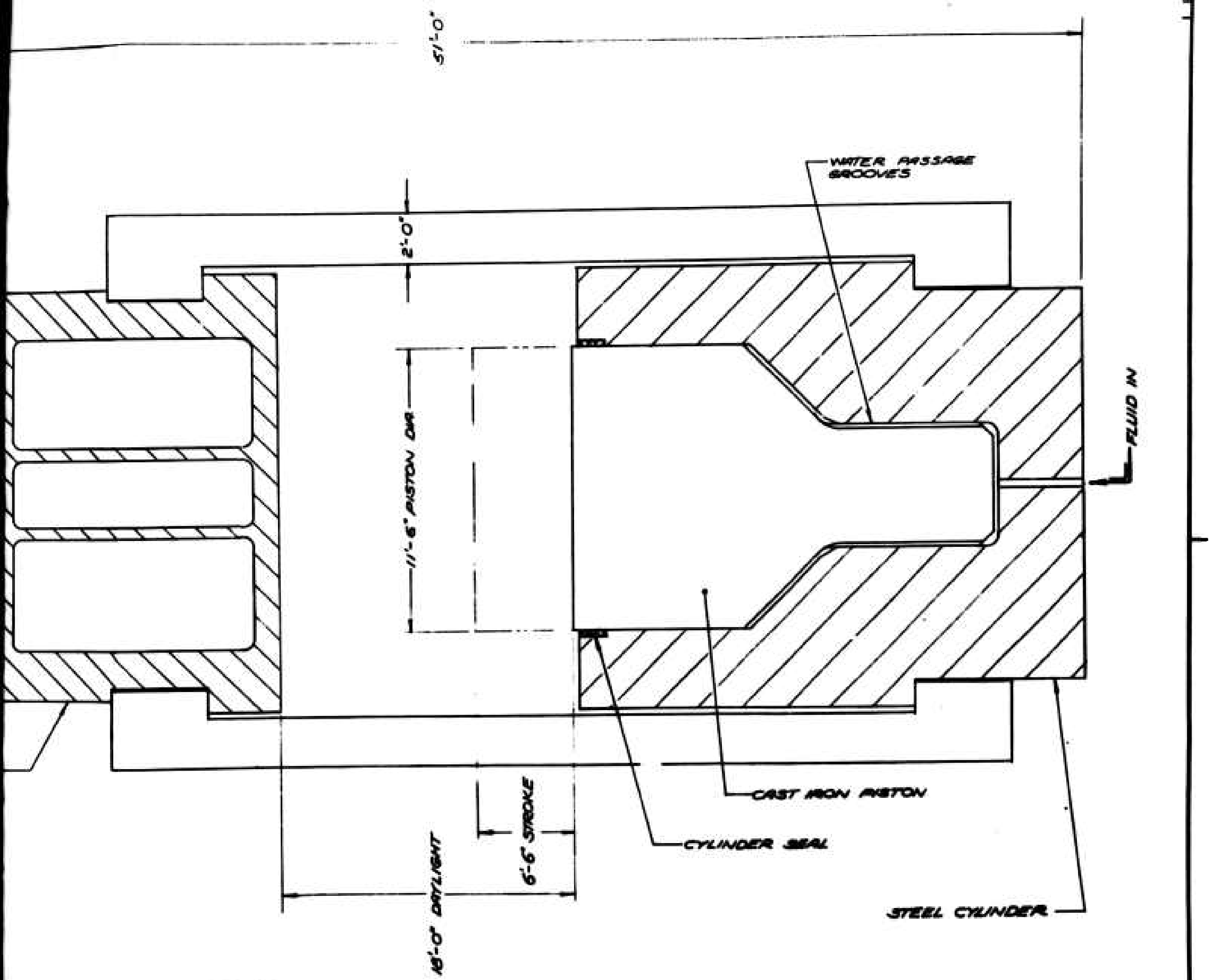
ESCO ARCHIVES | RUSSIAN 30,000 TON DIE FORGING PRESS | 306



1

PART LIST					
ITEM	NO. REQ.	NAME OF PART	MAT'L	WEIGHT	REMARKS
	1	CYLINDER	STL.	[illegible]	
	1	PISTON	CAST IRON	[illegible]	
	1	CROSSHEAD		[illegible]	
	60	PLATES	STL.	[illegible]	

TOTAL WT. = [illegible],046 APPROX.



2

UNLESS OTHERWISE SPECIFIED
TOLERANCE ± [illegible] ON ALL MACHINE DIMENSIONS
BREAK ALL [illegible]

THE DESIGN & INFORMATION SHOWN ON THIS DRAWING IS [illegible] TION OF [illegible] COMPANY.

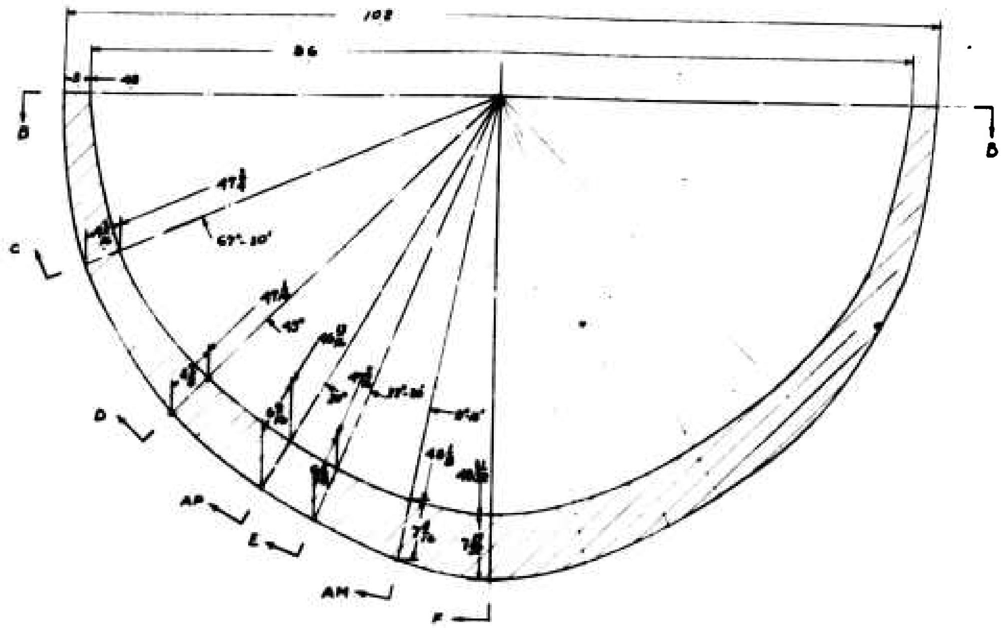
ENGINEERING SUPERVISION CO.
NEW YORK, U.S.A.

GENERAL ARRGT.
75,000 TON FORGING PRESS

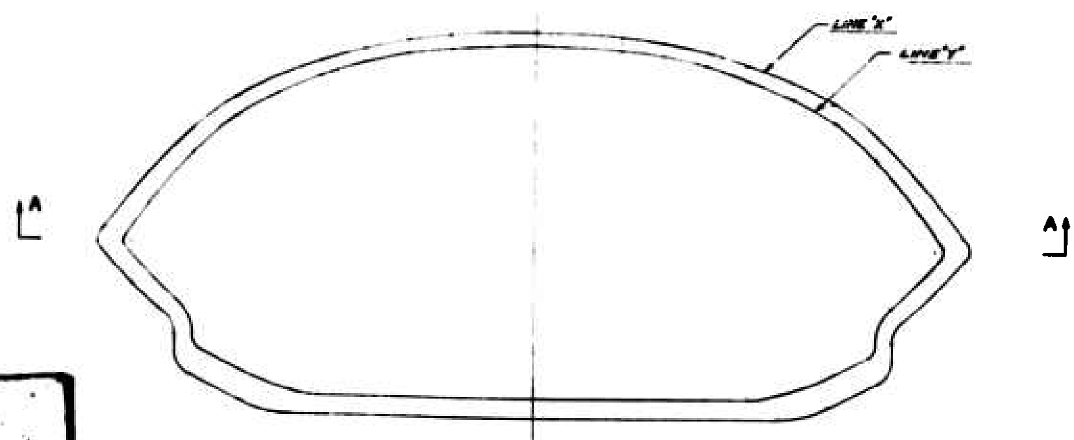
DATE
APPROVED BY
DATE
SCALE
D-12-1018

REV. | DATE | REVISION

* Not included in this report.



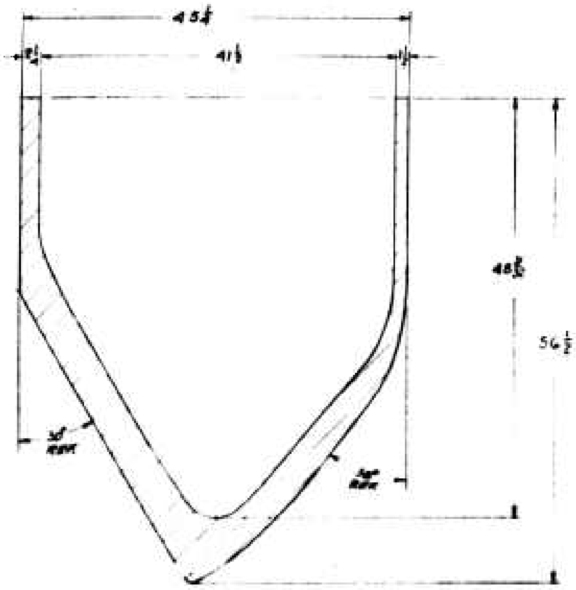
SECTION A-A



PLAN B-B

AREA CIRCUMSCRIBED BY LINE "X" = 3640 SQ. IN.
" " " " "Y" = 3140 " "

1



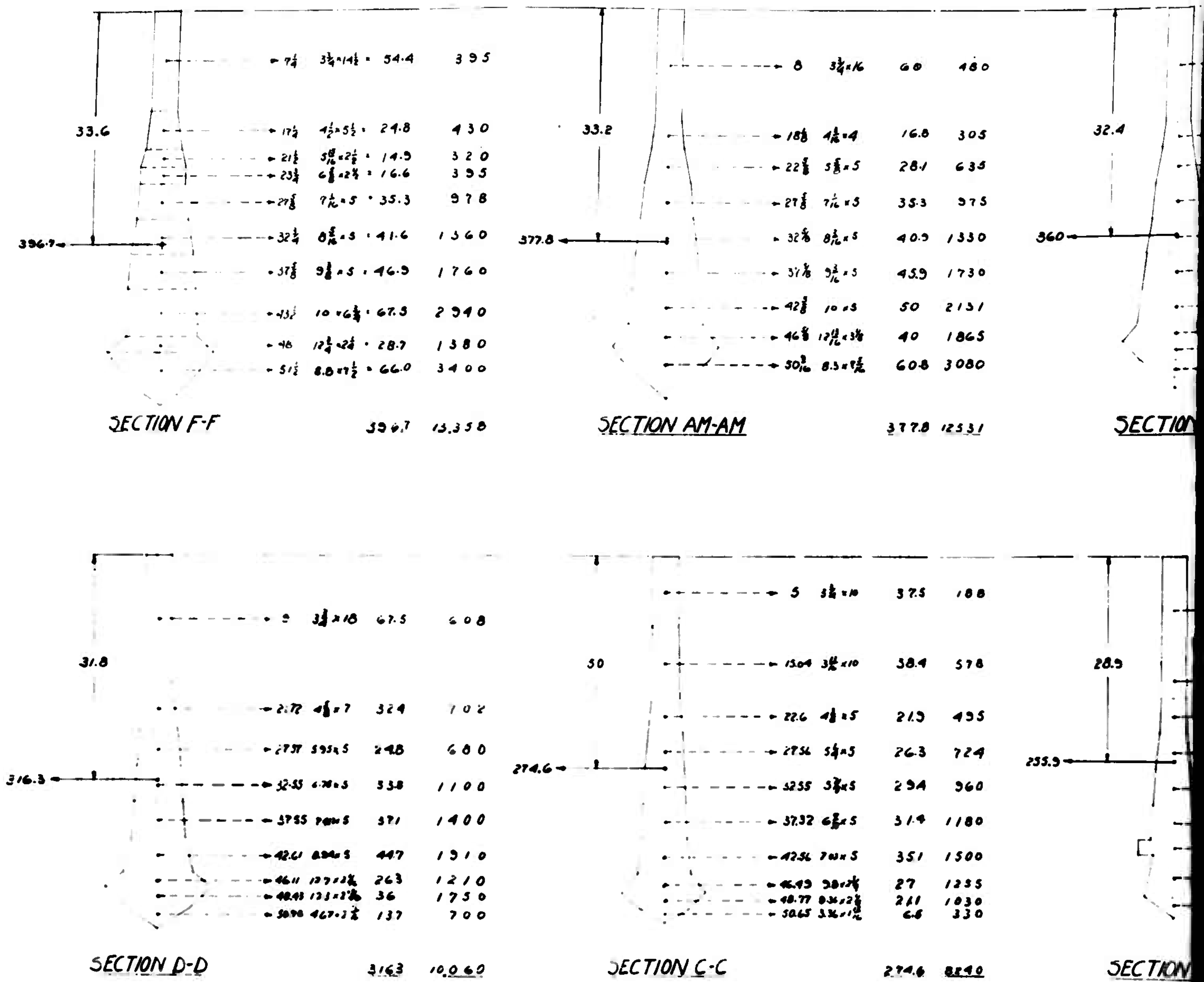
SECTION F-F

NOTES:
1) REFER TO DWG. K. 872/801-SHEETS 1 & 3 FOR LOCATION & DIMENSIONS OF SECTIONS
2) HEIGHTS CALCULATED ON ENG. SUPERVISION DWG. # 70-1128

V-133

ENGINEERING SUPERVISION CO. NEW YORK, U.S.A.	C. McG 8-1-38	M-48
		NOSE OF HULL BODY
		1/8"=1'-0" / 70-1121

REVISION



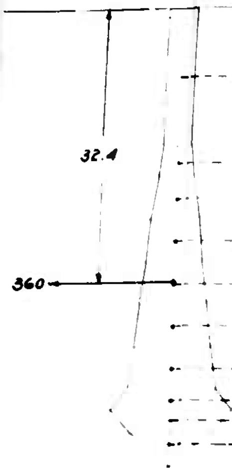
VOLUME = A × .01745 × 4 × θ

A = IN²
ȳ = CENTRE OF GRAVITY
θ = ROTATION IN DEGREES

SECTION	ROTATION	θ°	AREA"	C OF G. ȳ	VOLUME IN³	MEAN VOLUME IN³
F	F TO AM	11°-15'	396.7	33.6	2610	2535
AM	AM TO F	"	377.8	33.2	2460	
AM	AM TO E	"	377.8	33.2	2460	2375
E	E TO AM	"	360	32.4	2230	
E	E TO AP	7°-30'	360	32.4	1530	1510
AP	AP TO E	"	353.8	32.1	1490	
AP	AP TO D	15°	353.8	32.1	2580	2810
D	D TO AP	"	316.3	31.8	2640	
D	D TO C	22°-30'	316.3	31.8	3360	3600
C	C TO D	"	274.6	30	3240	
C	C TO B	"	274.6	30	3240	3070
B	B TO C	"	255.3	28.9	2900	
		90°				Σ = 15,900

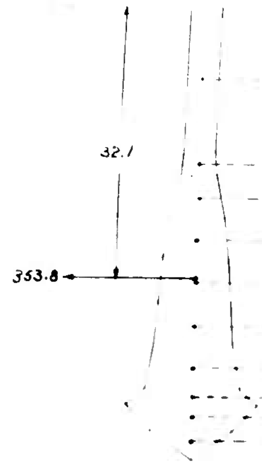
180° = 31,800 in³

WEIGHT OF NOSE IN STEEL = 31,800 × .2816 = 8950#



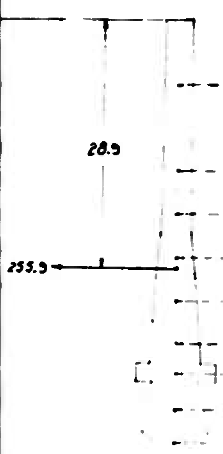
$8\frac{1}{4}$	$3\frac{3}{4} \times 16\frac{1}{2}$	61.9	510
18.5	$4\frac{5}{32} \times 3\frac{1}{2}$	14.6	267
22.65	$5\frac{1}{2} \times 5$	27.5	624
27.55	$6\frac{13}{16} \times 5$	34.1	940
32.58	$7\frac{15}{16} \times 5$	39.7	1300
37.53	9.22×5	46.1	1735
42.53	10.36×5	51.8	2200
46.22	$13\frac{1}{16} \times 2\frac{5}{16}$	30.3	1400
48.57	$12.44 \times 2\frac{3}{4}$	34	1650
$51\frac{1}{16}$	$51 \times 3\frac{15}{16}$	20	1026
		360.0	11652

SECTION E-E



$9\frac{3}{16}$	$3\frac{3}{4} \times 17\frac{1}{2}$	65.6	560
18.6	$3\frac{11}{32} \times 2\frac{7}{8}$	11.4	214
22.66	5.34×5	26.7	605
27.56	$7\frac{1}{16} \times 5$	35.3	975
32.55	$8\frac{1}{16} \times 5$	40.3	1320
37.55	8.89×5	44.5	1670
42.57	10.14×5	50.7	2160
45.97	$13\frac{1}{8} \times 1\frac{13}{16}$	24	1105
48.29	$10.34 \times 3\frac{1}{16}$	39.4	1900
$51\frac{1}{8}$	$4\frac{11}{32} \times 3\frac{1}{8}$	15.9	815
		353.8	11,324

SECTION AP-AP



7.55	$3\frac{13}{16} \times 15$	57.3	432
17.5	$3\frac{7}{8} \times 5$	19.4	340
22.53	4×5	20	451
27.6	4.66×5	23.3	643
32.56	$5\frac{5}{8} \times 5$	28.1	915
37.54	$6\frac{11}{32} \times 5$	31.7	1190
41	10×2	20	820
45.17	$7\frac{1}{8} \times 6$	43.5	1965
49	$4\frac{1}{4} \times 3$	12.6	625
		255.9	7391

SECTION B-B

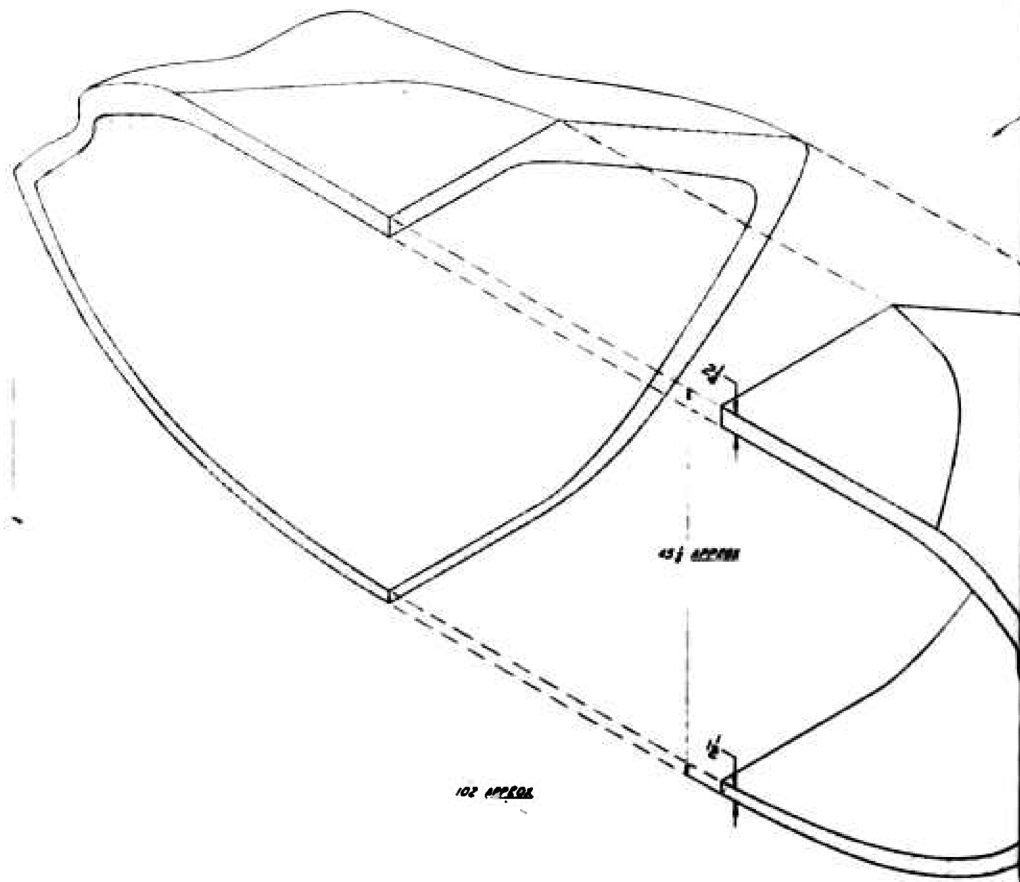
2

SEE "NOSE OF HULL BODY"
ESCO DRAWING 70-1121

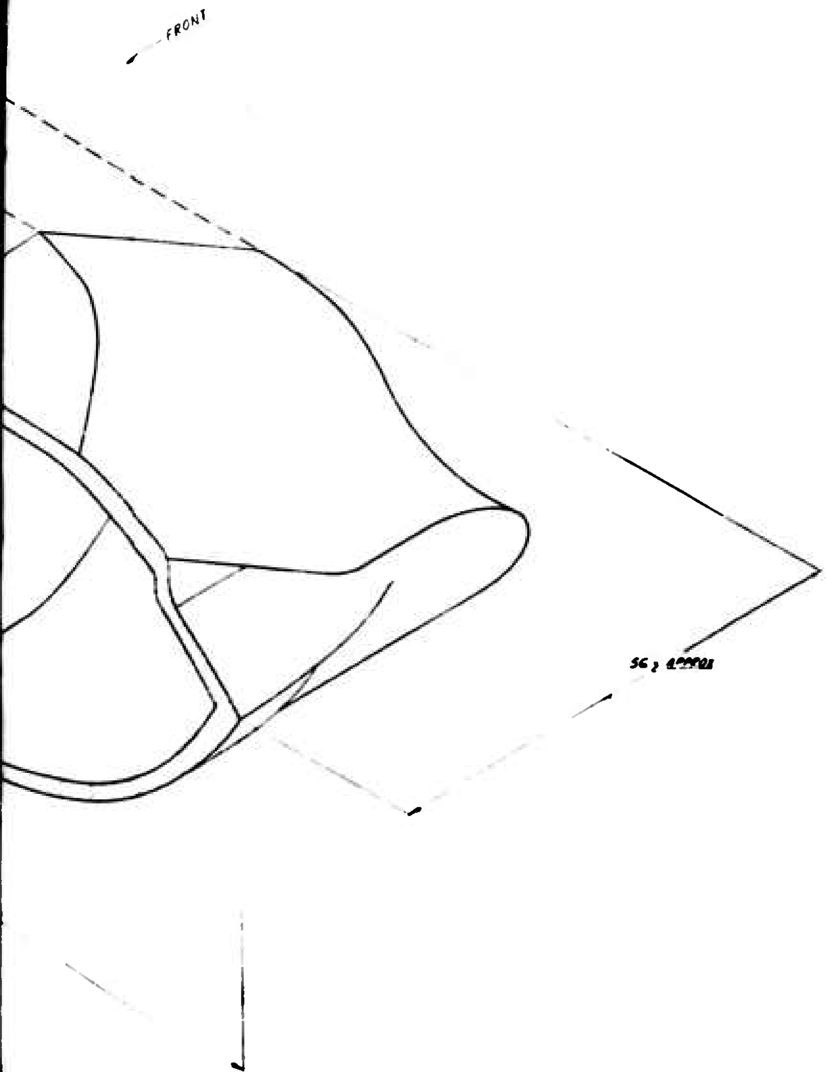
J-139

ENGINEERING SUPERVISION CO. NEW YORK, U.S.A.	DRAWN BY C.M.G DATE	M-48	
	CHECKED BY DATE	WEIGHT OF HULL BODY NOSE	
TO REPLACE / REPLACED BY / AD. DWG.	APPROVED BY DATE	SCALE $1\frac{1}{2}" = 1'-0"$	DRAWING NUMBER 70-1122

REVISION



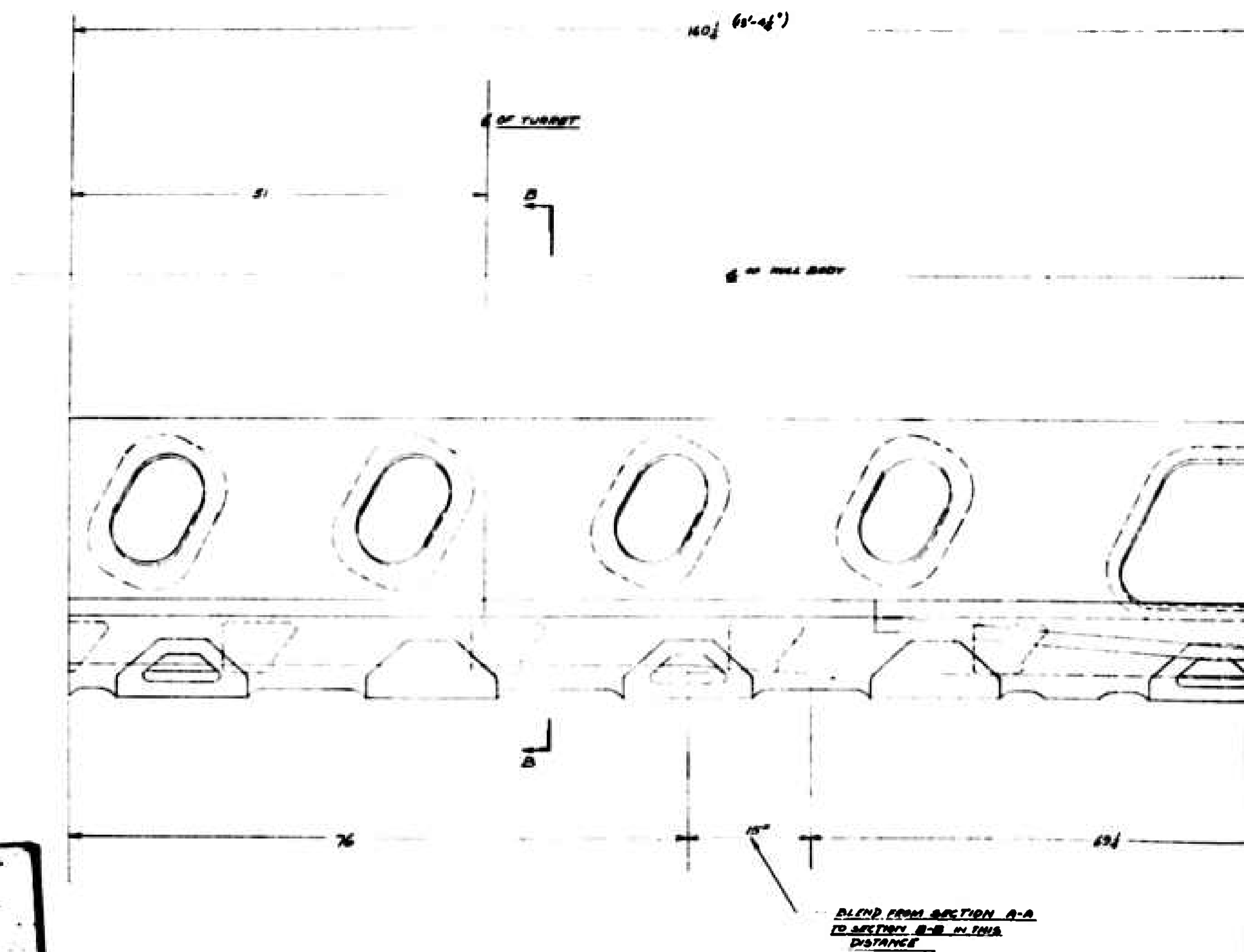
1



J-139

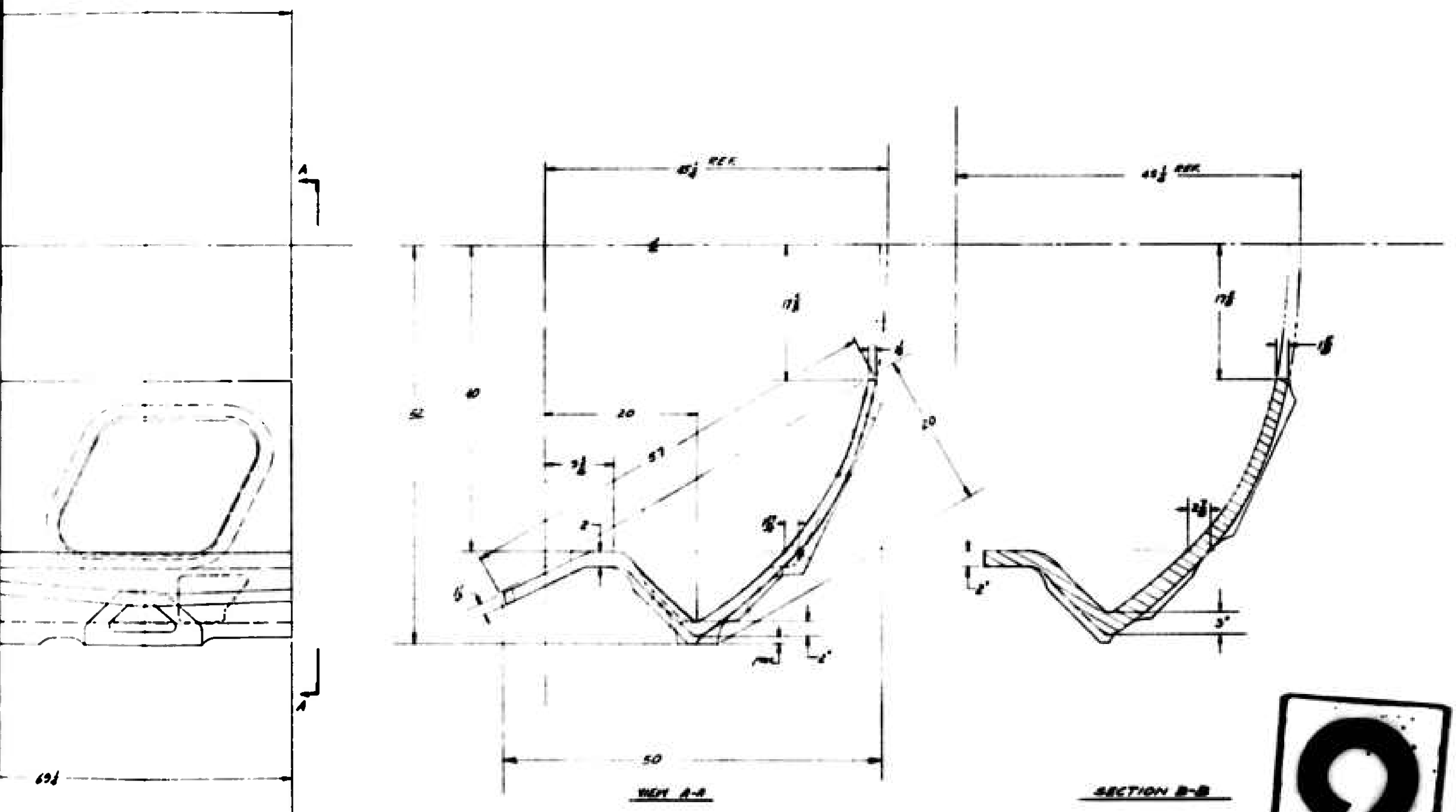
ENGINEERING SUPERVISION CO. 743 FIFTH AVE. NEW YORK, U.S.A.	DRAWN BY M J P	M-48
		NOSE OF HULL BODY - PROFILE
	SCALE NOT TO SCALE	DRAWING NUMBER 70-1123

REVISION



160¼ (13'-4¼")
℄ OF TURRET
51
B
℄ OF HULL BODY
B
76
15"
69¼
BLEND FROM SECTION A-A TO SECTION B-B IN THIS DISTANCE

1



NOTES:

1) REFER TO DWG. # K 6721801, SHEETS 1,2 & 3

2) APPROXIMATE WEIGHTS IN STEEL, PER EACH SIDE PLATE (2-REQD.)

a) WITHOUT PADS : 5180#

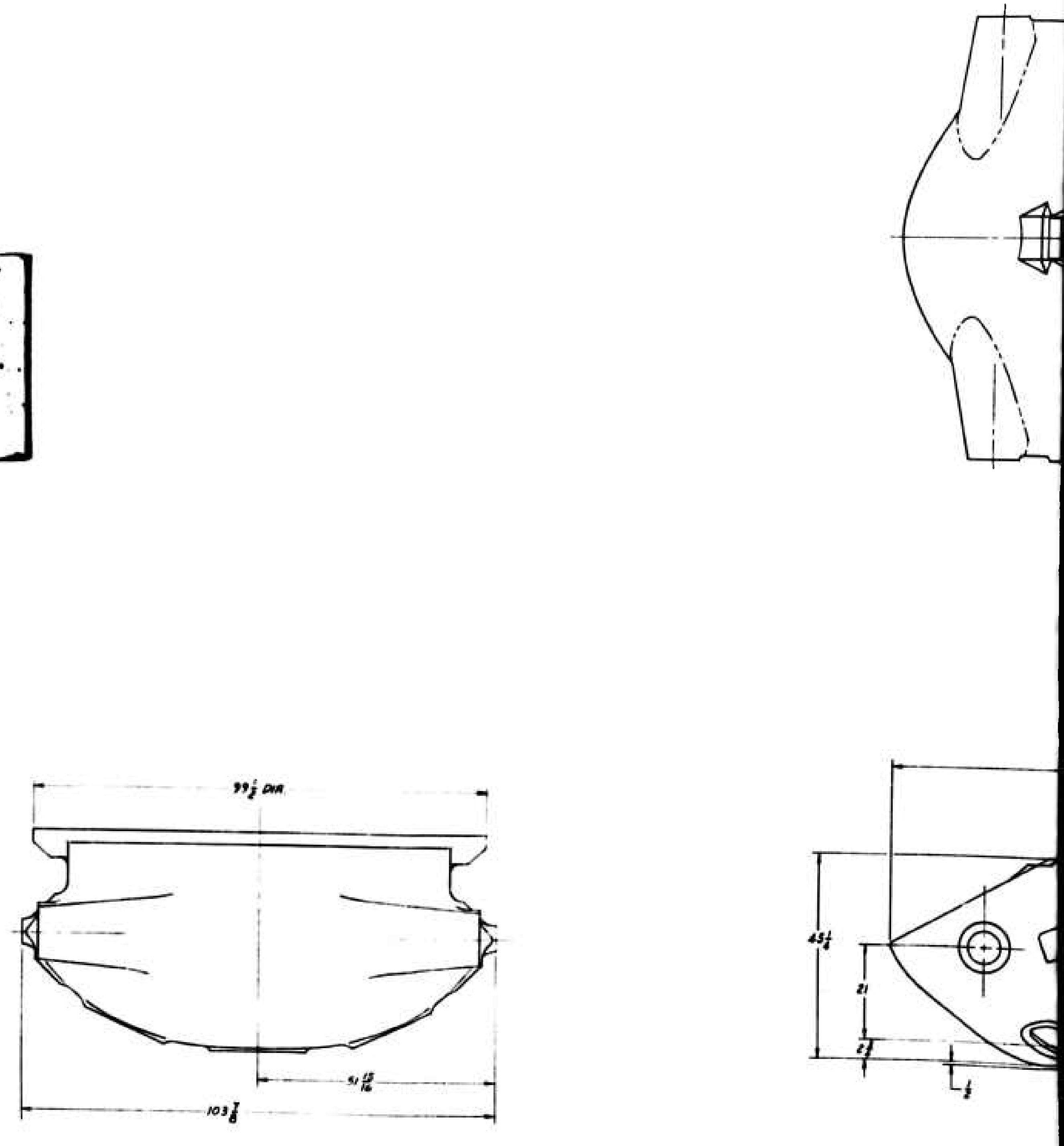
b) WITH PADS : 5400#

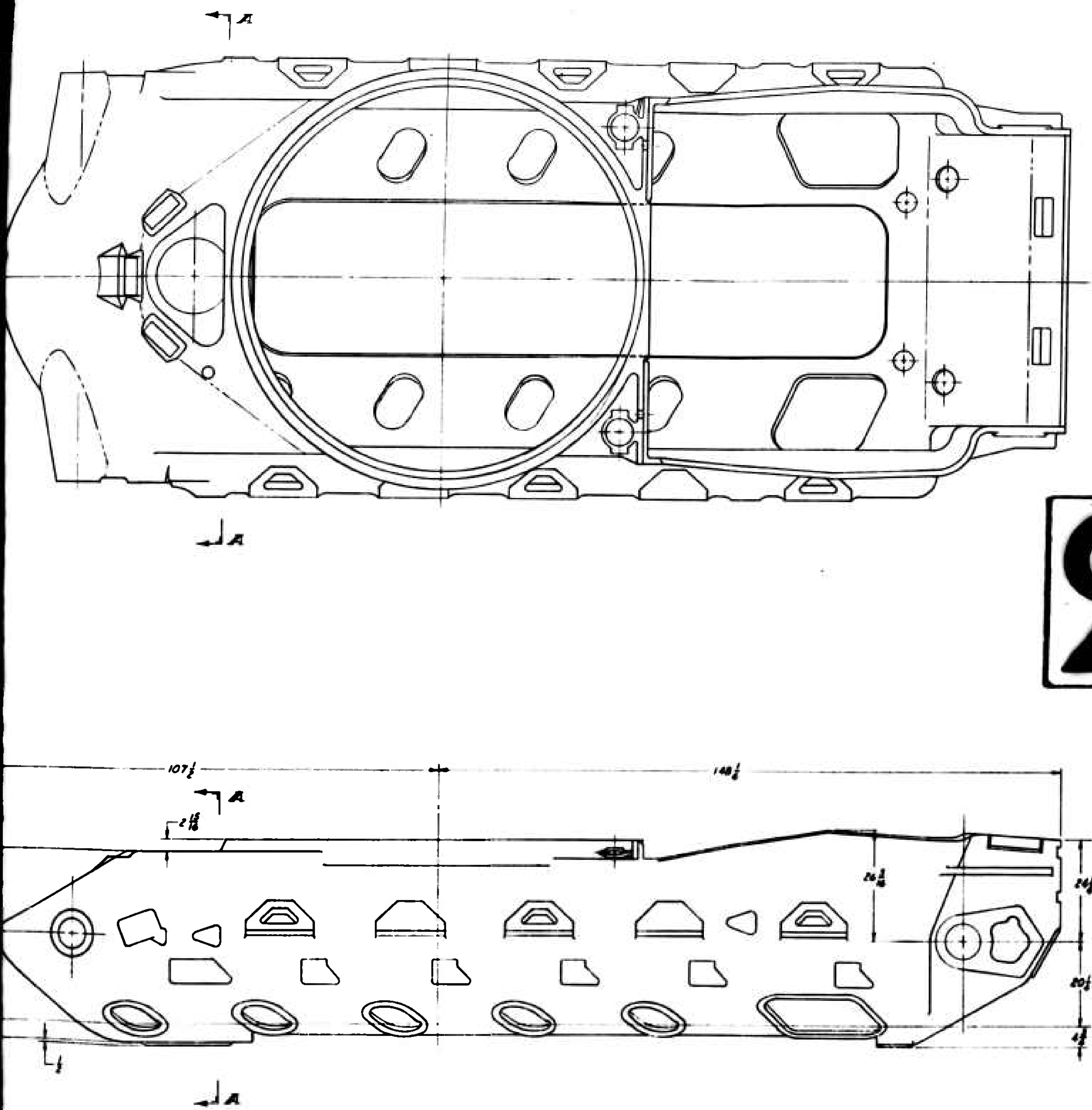
c) WITH HOLES PUNCHED : 5000#

J-139

ENGINEERING SUPERVISION CO. NEW YORK, U.S.A.		M-48
		SIDE OF HULL BODY
REVISION	SCALE $1\frac{1}{2}"=1'-0"$	70-1124

1





2

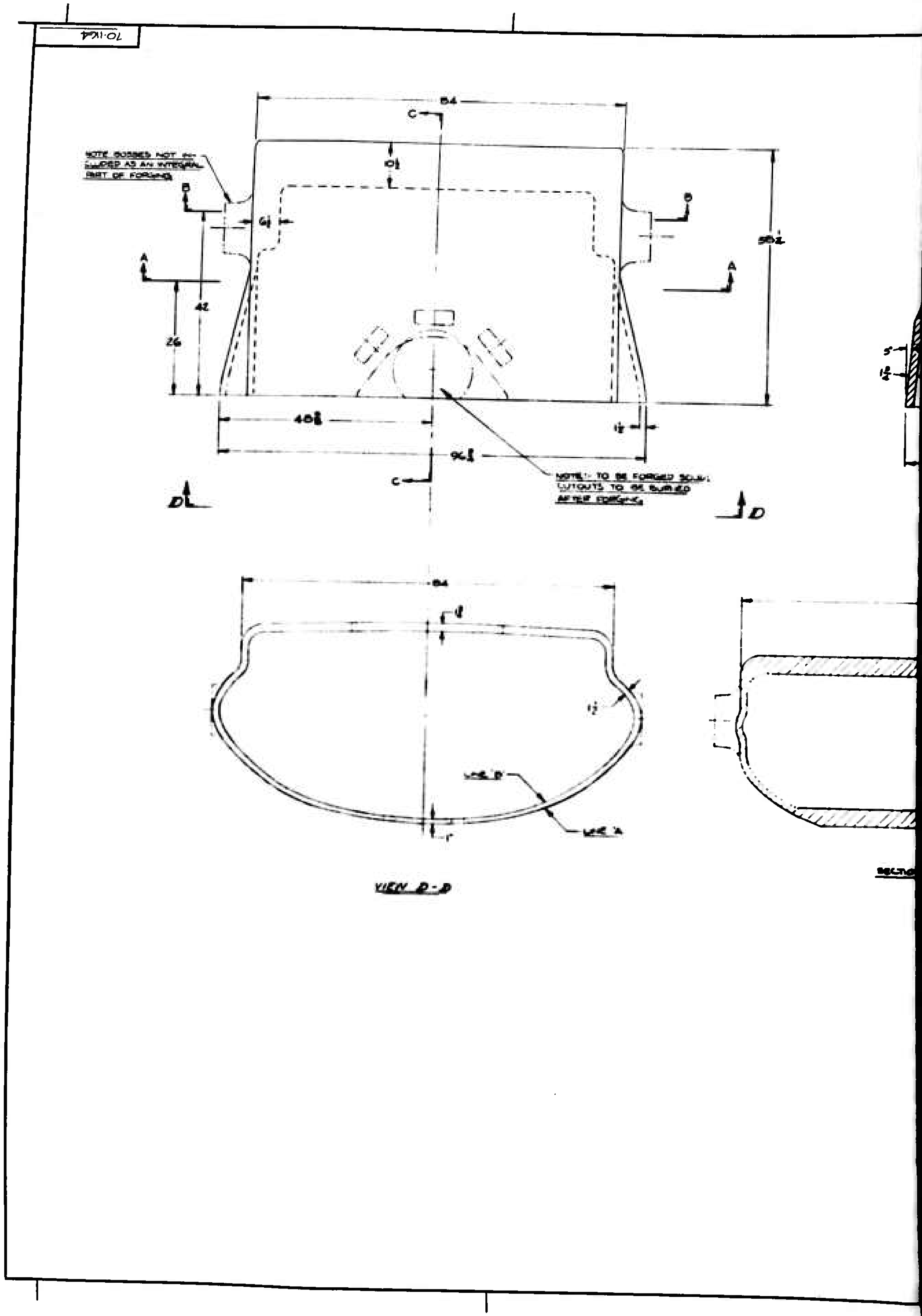
J-139

ENGINEERING SUPERVISION CO.
743 FIFTH AVE.
NEW YORK, U.S.A.

M-48

HULL BODY

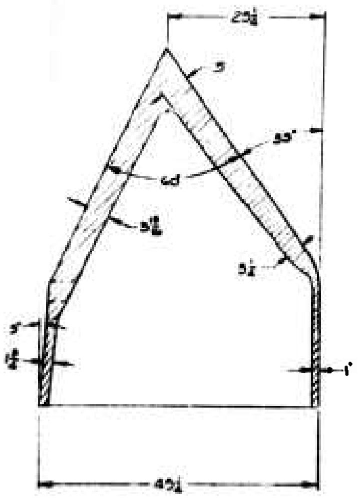
REV. NO.	DATE	REVISION	SCALE	DRAWING NUMBER
			1" = 1'-0"	E-70-1126


10·164
84
C
10 1/2
NOTE BOSSES NOT IN-
CLUDED AS AN INTEGRAL
PART OF FORGING
B
6 1/4
A
42
26
58 1/2
40 3/8
96 3/8
1 1/2
NOTE:- TO BE FORGED SOLID;
CUTOUTS TO BE BURNED
AFTER FORGING.
D
84
1 1/2
VIEW D-D

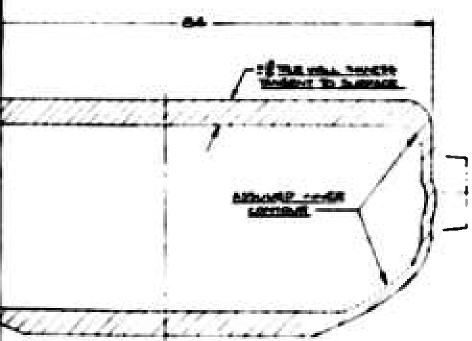
1

PART LIST

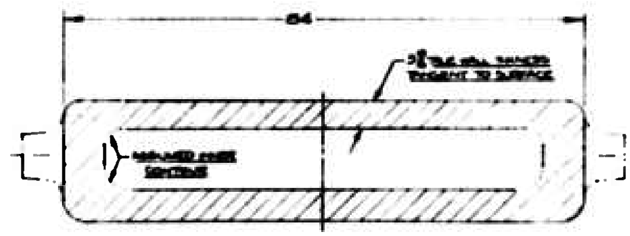
ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT.	FINISHED TOTAL WT.	REMARKS



SECTION C-C



SECTION A-A



SECTION B-B

APPROX. WEIGHT - 10100 LBS.

APPROX. AREA - LINE 'A' - 3,640 SQ IN.

APPROX. AREA - LINE 'B' - 3265 SQ IN.

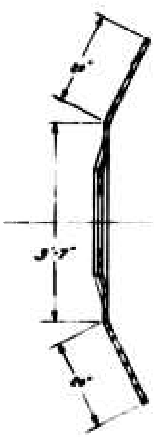
2

J-139

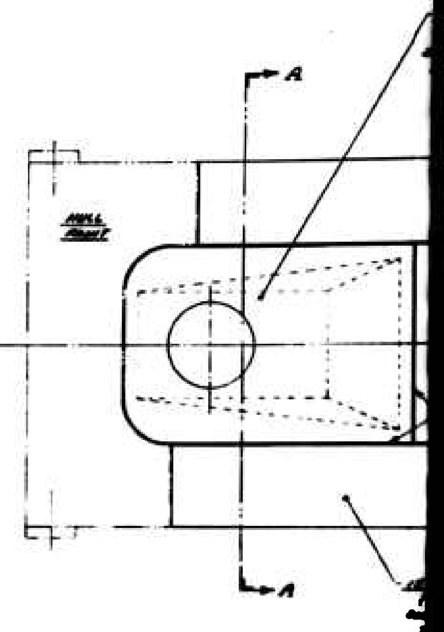
ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	DRAWN BY: DATE 10-27-50	MODIFIED TANK HULL NOSE
	CHECKED BY: DATE	FORGING FOR MEDIUM TANK
TO REPLACE / REPLACED BY / ASSEL. DWGS.	APPROVED BY: DATE 10-31	SCALE 1" = 1'-0" / DRAWING NUMBER 70-1164

REV. NO.	DATE	REVISION	CHKD BY	CHKD BY

70-1166

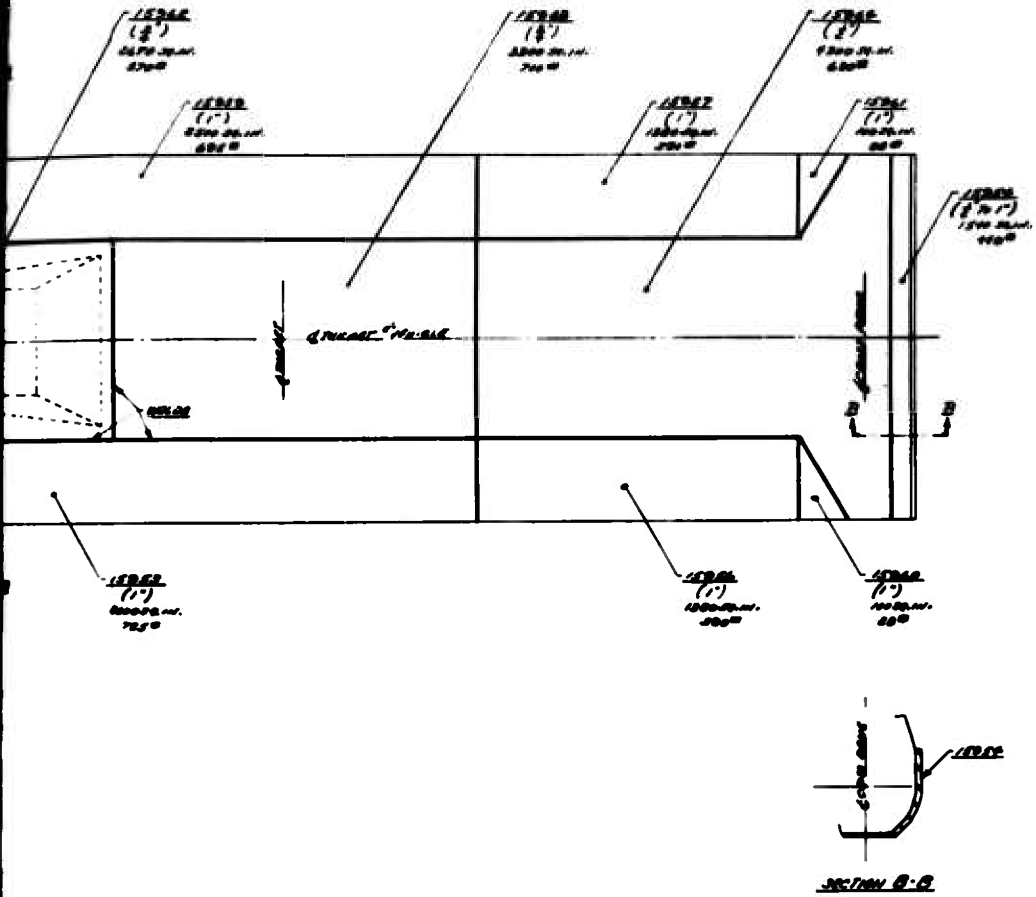


SECTION A-A



1

PART LIST						
ITEM	NO. REQ.	NAME OF PART	MAT'L			REMARKS



NOTE:
FOR PART NUMBERS INDICATED ON THIS DRAWING SEE REFERENCE DRAWINGS SUPPLIED BY ORDNANCE DEPT. DEPARTMENT OF THE ARMY - DETROIT ARSENAL.

J-139

UNLESS OTHERWISE SPECIFIED
TOLERANCE ± .010 ... DIMENSIONS.
BREAK ALL SHARP C...

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

FLOOR PLATE ASSY.

70-1166

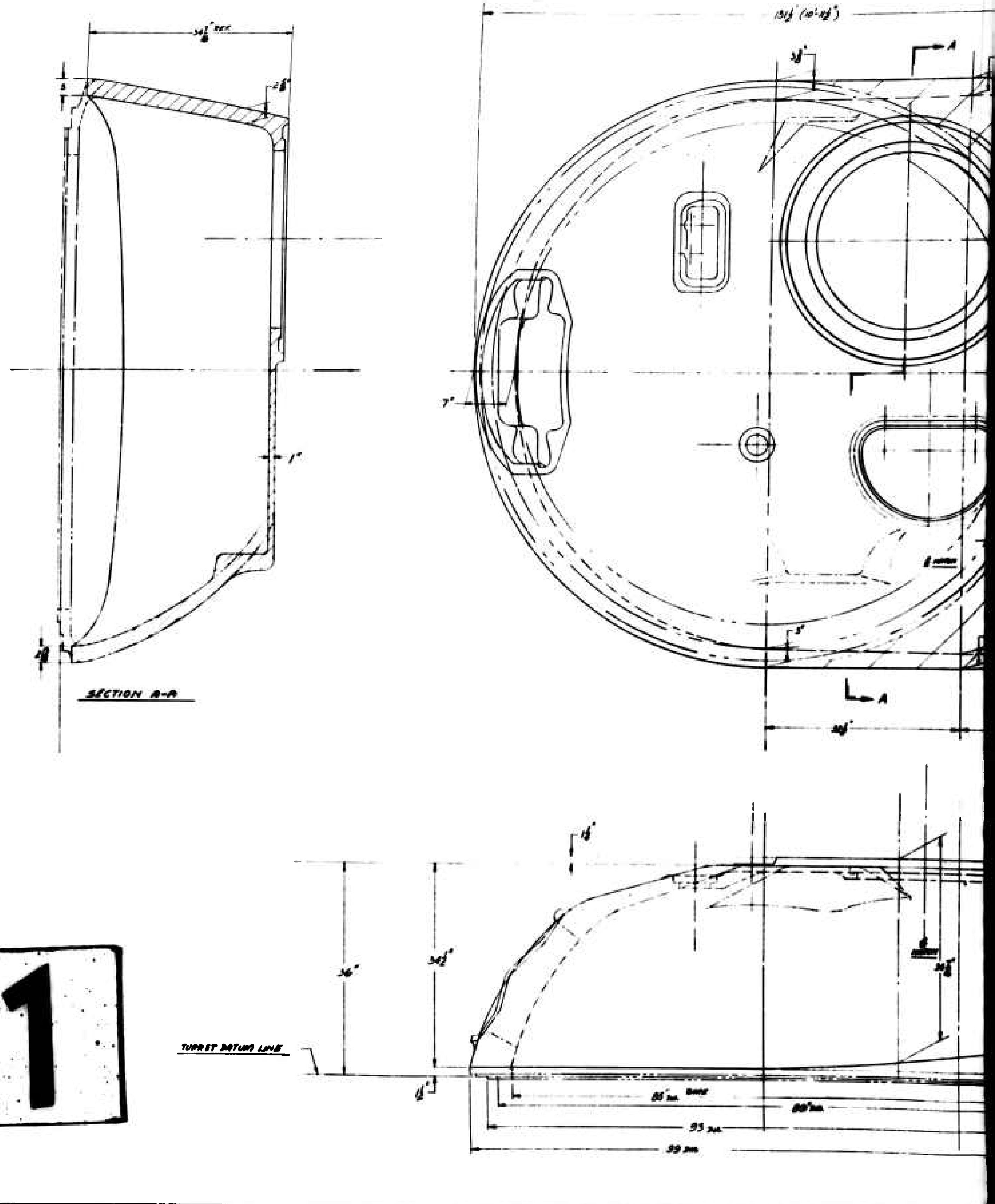
REVISION

Part

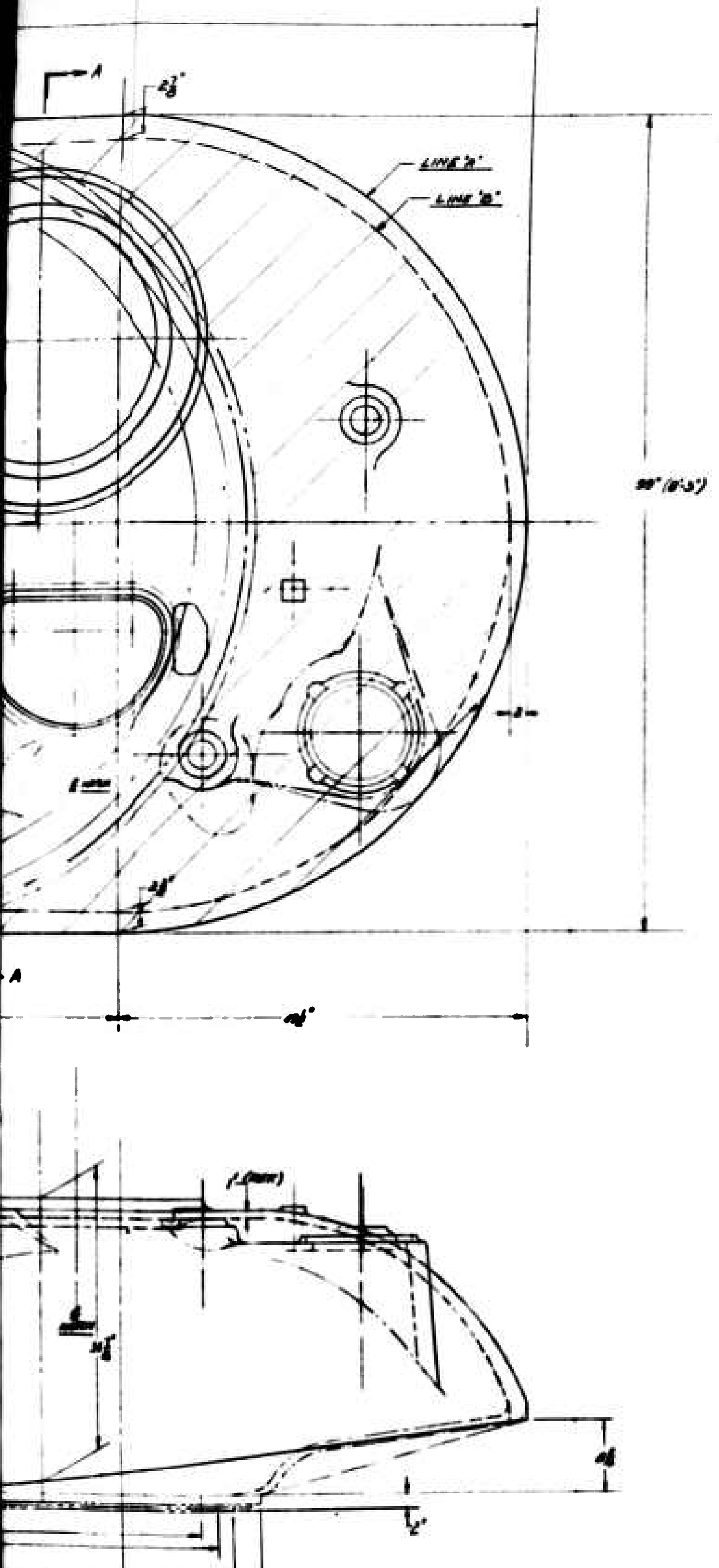
XXVII Drawings Pertaining to the Turret

70-1129*
70-1130
70-1134
70-1135
70-1136
70-1137
70-1138
70-1139
70-1140
70-1141
70-1142
70-1143
70-1144
70-1145
70-1153
70-1162
70-1163

* Not included in this report.



1

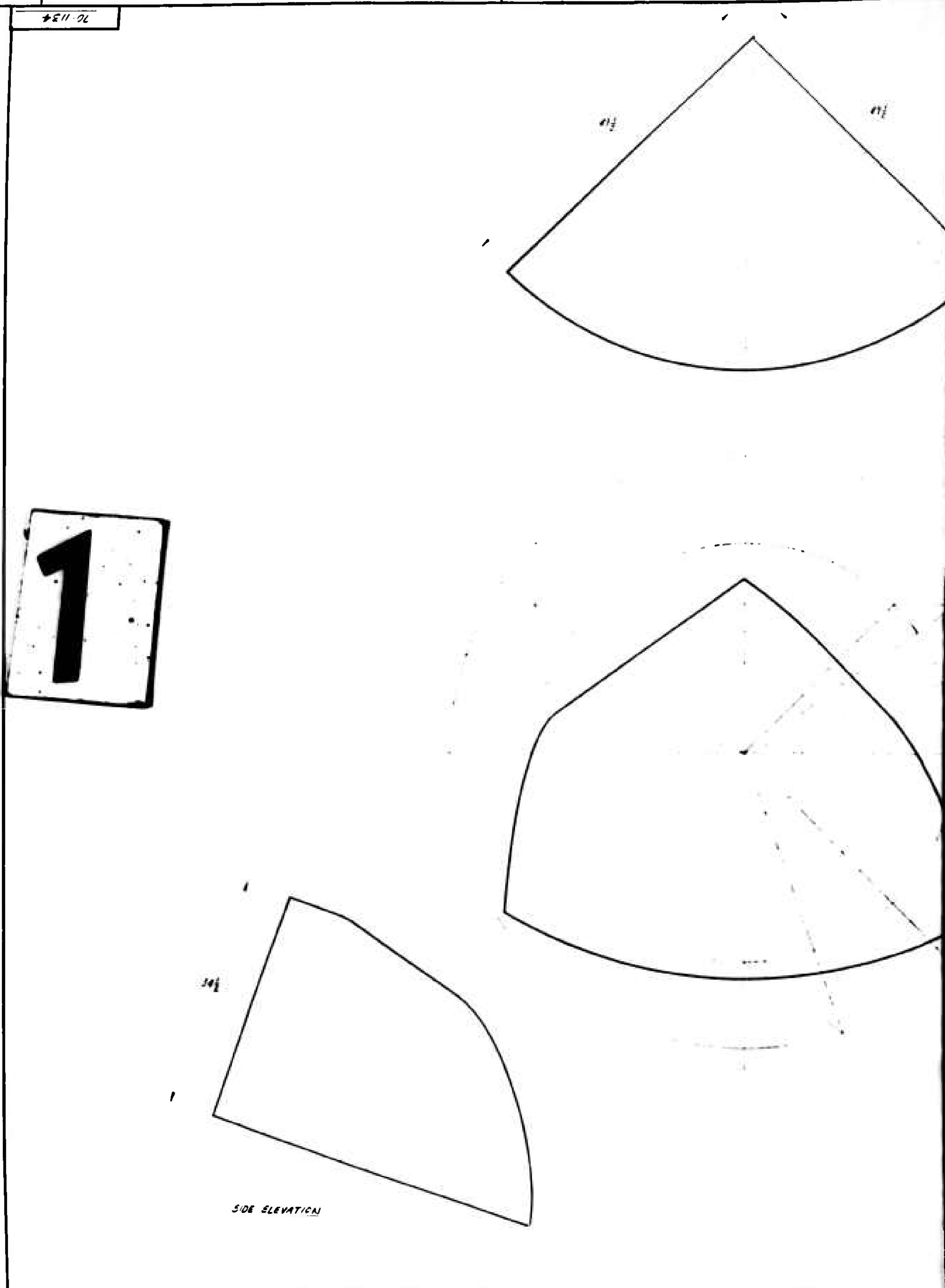


NOTES:
1) AREA CIRCUMSCRIBED BY LINE "A" = 10,800 SQ. IN.
2) AREA CIRCUMSCRIBED BY LINE "B" = 10,250 SQ. IN.
3) ESTIMATED WEIGHT: 9,600 LB.
4) FOR REFERENCE SEE DWG. # 8694367 SHEET 1

J-139

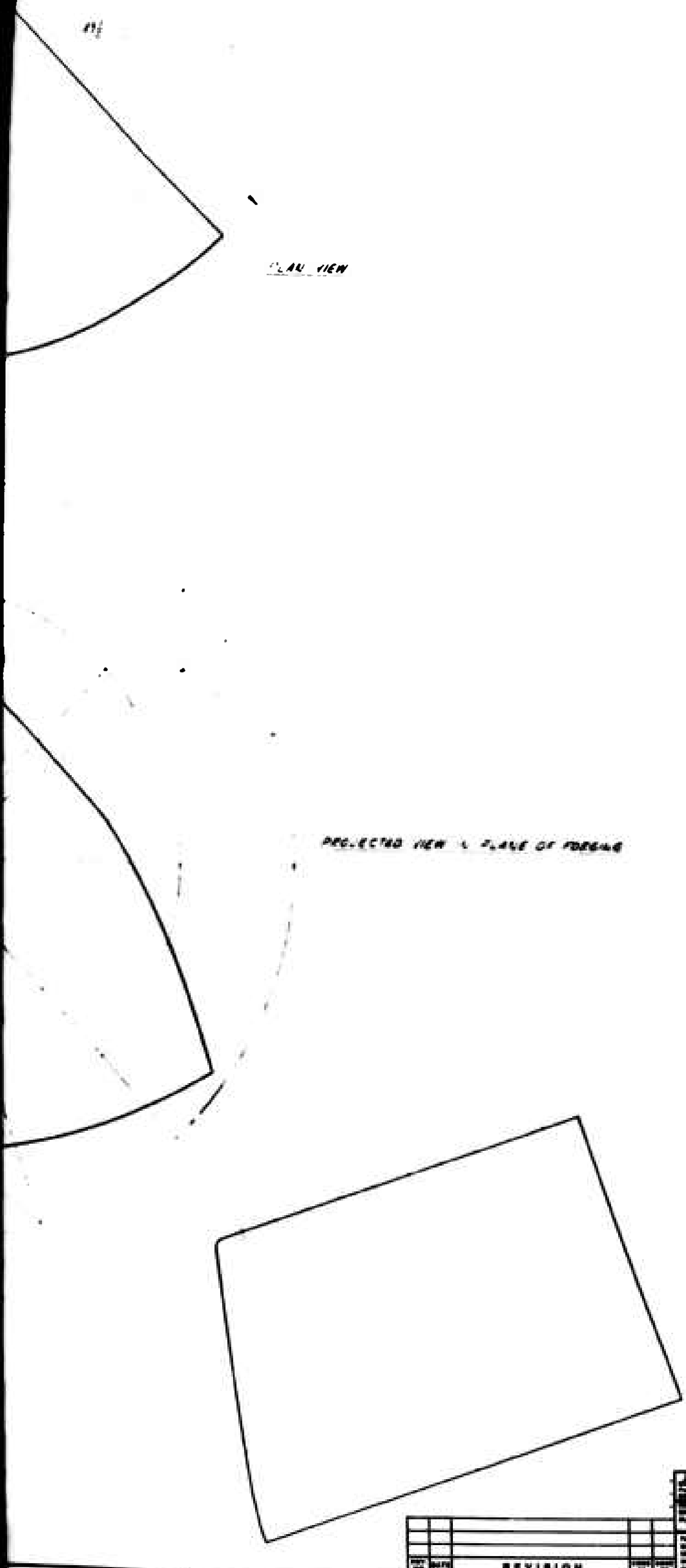
ENGINEERING SUPERVISION CO. NEW YORK, U.S.A.	DATE	M-48	
	DATE	TURRET	
TO REPLACE / REPLACED BY / ASSC. DWG.	APPROVED BY / DATE	SCALE $\frac{1}{2}$" = 1'-0"	DRAWING NUMBER 70-1130

REVISION


SIDE ELEVATION

PART LIST

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT.	TOTAL WT.	REMARKS

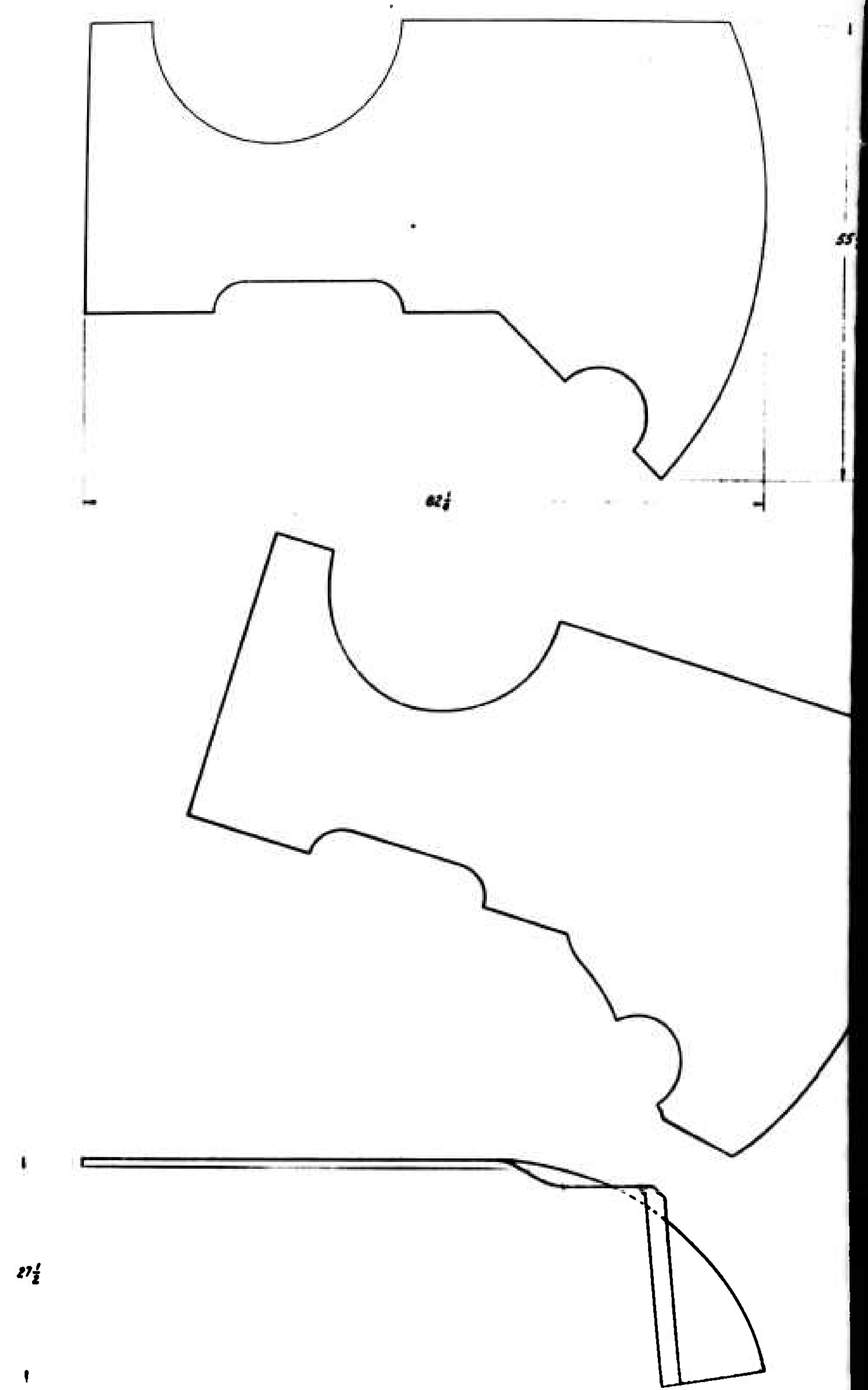


2

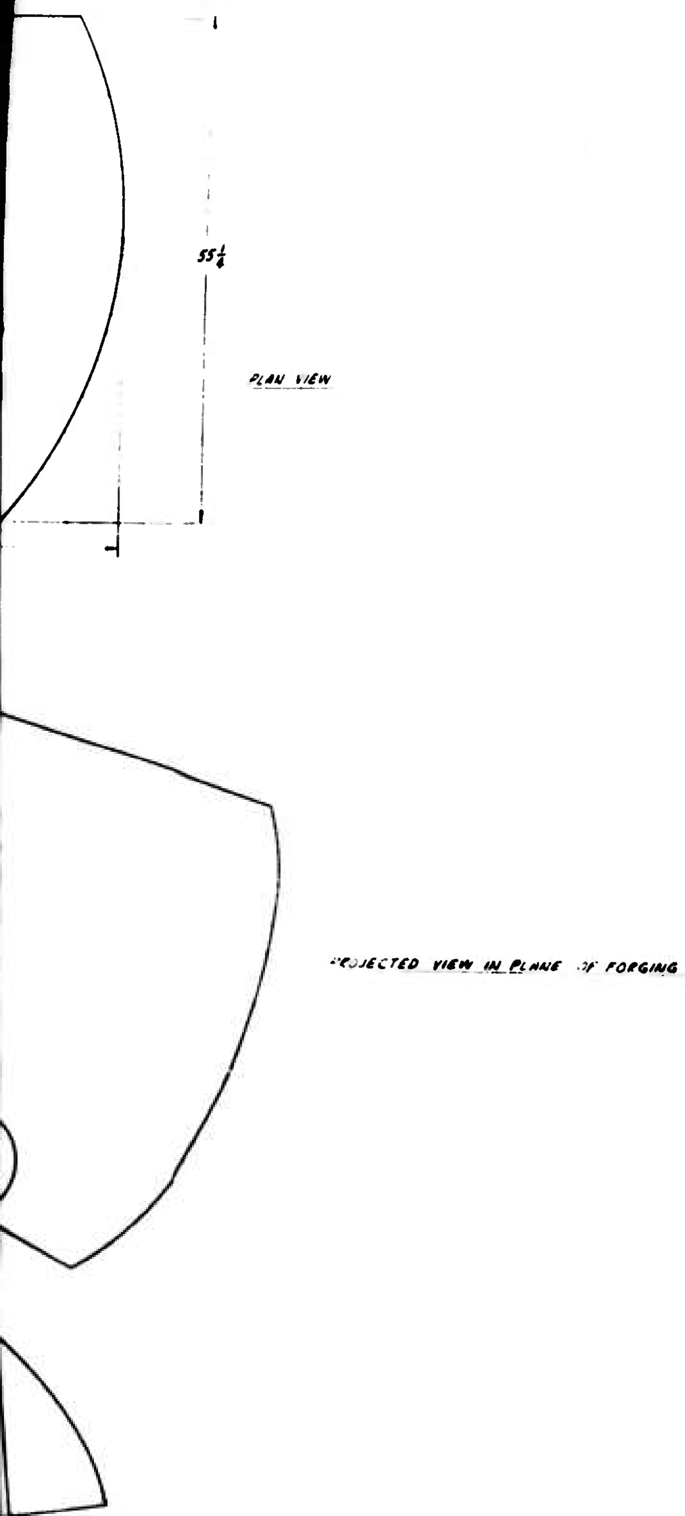
J-139

ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	DRAWN BY M.J.P. DATE 8-5-38	M-48	
	CHECKED BY DATE	TURRET · COMP'S 'A' & 'B' NOSE: RIGHT SIDE PROJECTION	
TO REPLACE / REPLACED BY / ASSL. DWG.	APPROVED BY DATE	SCALE 1/2"=1'-0"	DRAWING NUMBER 70-1134

REVISION



SIDE ELEVATION



PART LIST

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED		REMARKS

2

J-139

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

DRAWN BY M.J.P
DATE 8-5-50
CHECKED BY
DATE
APPROVED BY
DATE

M-48

TURRET - COMP. "A"
CENTER REAR PROJECTION

SCALE $1\frac{1}{2}" = 1'-0"$

DRAWING NUMBER 70-1135

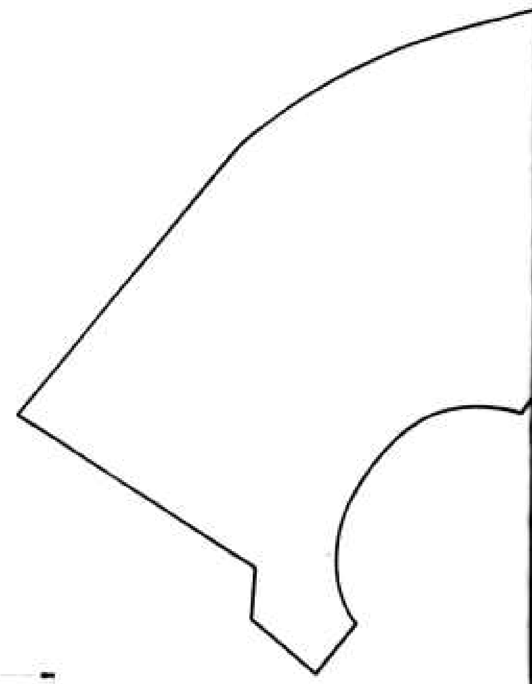
THIS DRAWING IS DESIGN AND DETAILS IS OUR PROPERTY AND IS TO BE USED ONLY IN CONNECTION WITH OUR WORK. ALL RIGHTS RESERVED

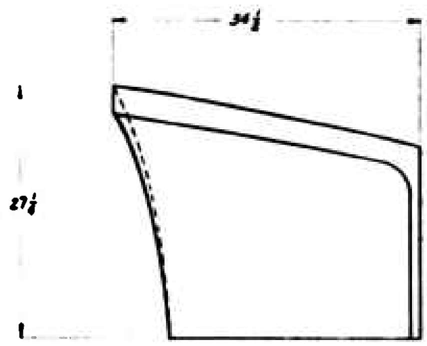
TO REPLACE | REPLACED BY | ASSY. DWG.

REV. | DATE | REVISION | CHGD BY | CHKD BY

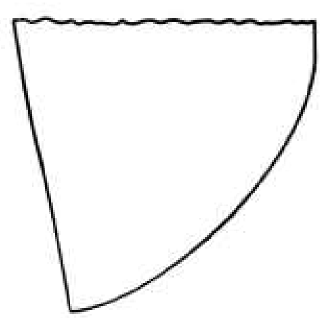
70-1136

1



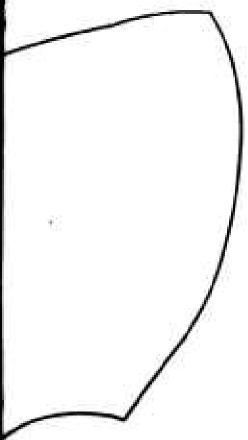


FRONT ELEVATION



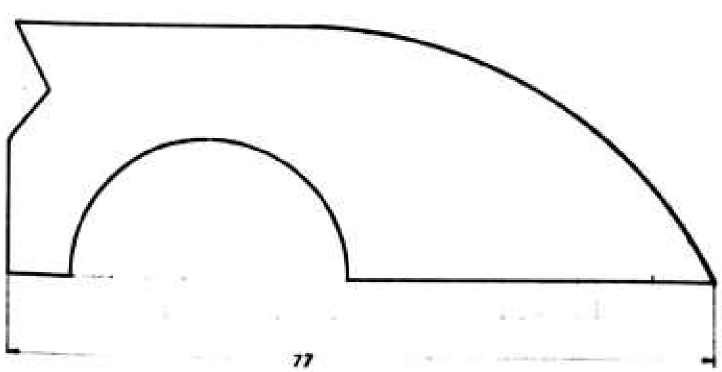
PARTIAL SIDE ELEVATION

PART LIST						
ITEM		NAME OF PART	MAT'L			REMARKS



PROJECTED VIEW IN PLANE OF FORGING

2



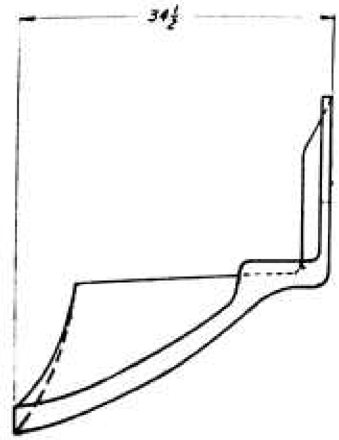
PLAN VIEW

J-139

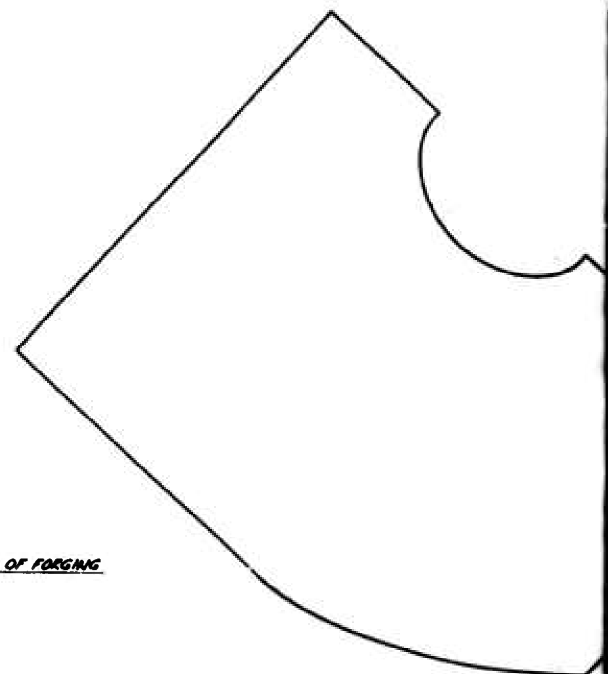
ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	DRAWN BY M.J.P DATE 8-6-58	M-48	
	CHECKED BY DATE A	TURRET - COMP. A RIGHT REAR PROJECTION	
TO REPLACE / REPLACED BY / ASSY. DWG.	APPROVED BY DATE	SCALE 1½" - 1'-0"	DRAWING NUMBER 70-1136

REV. NO.	DATE	REVISION	CHKD BY	APPD BY

70-1137



FRONT ELEVATION

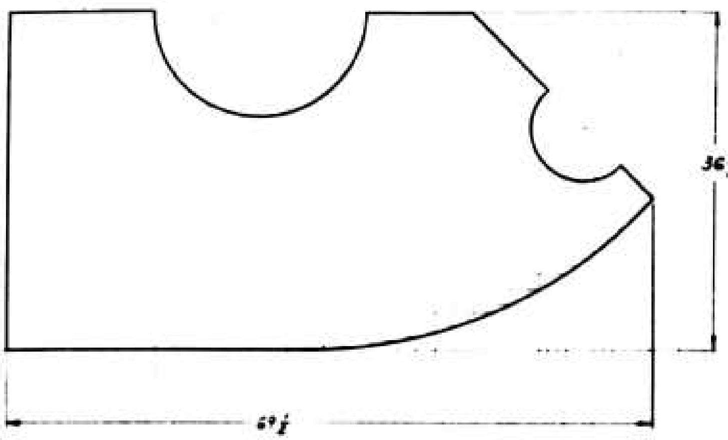


PROJECTED VIEW IN PLANE OF FORGING

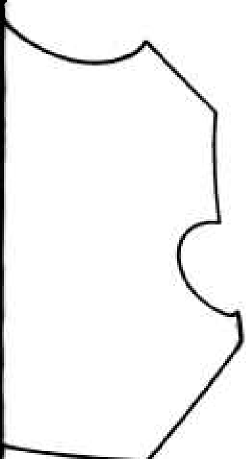
1

PART LIST

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT.	FINISHED TOTAL WT.	REMARKS



PLAN VIEW



2

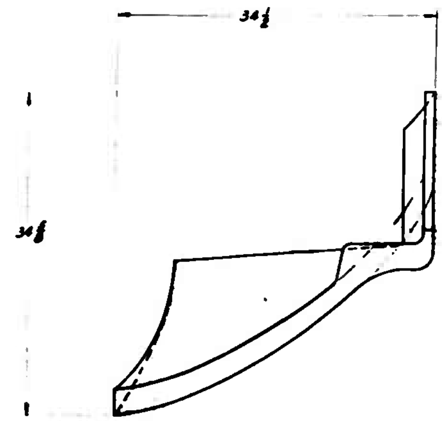
J-139

ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	
DRAWN BY M.J.P	M-48
DATE 8-4-52	
CHECKED BY	TURRET-COMP. "A"
DATE	LEFT REAR PROJECTION
APPROVED BY	SCALE 1/2" = 1'-0"
DATE	DRAWING NUMBER 70-1137

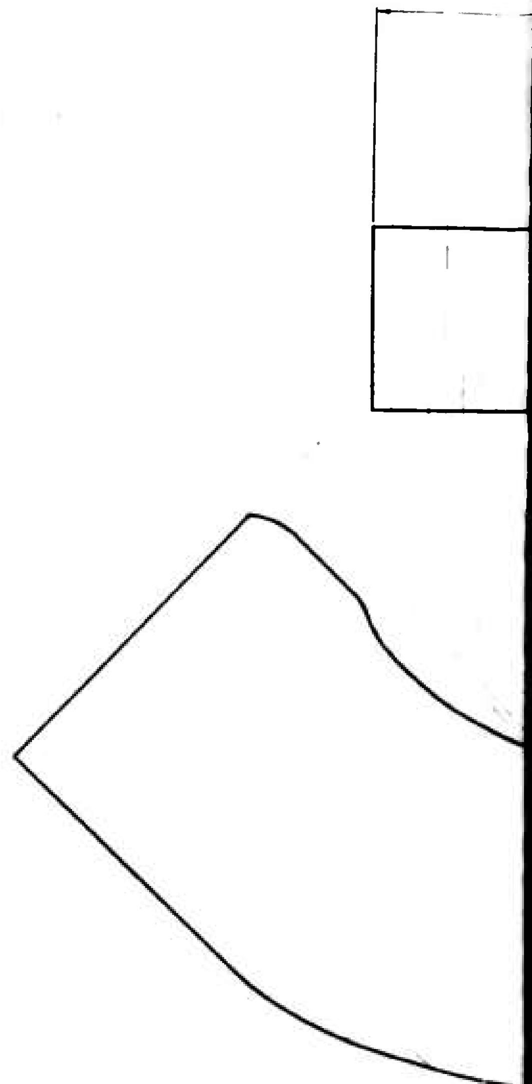
THIS DRAWING IN DESIGN AND DETAILS IS OUR PROPERTY AND IS TO BE USED ONLY IN CONNECTION WITH OUR WORK. ALL RIGHTS RESERVED.

REV. NO.	DATE	REVISION	CHKD BY	CHKD BY

70-1158

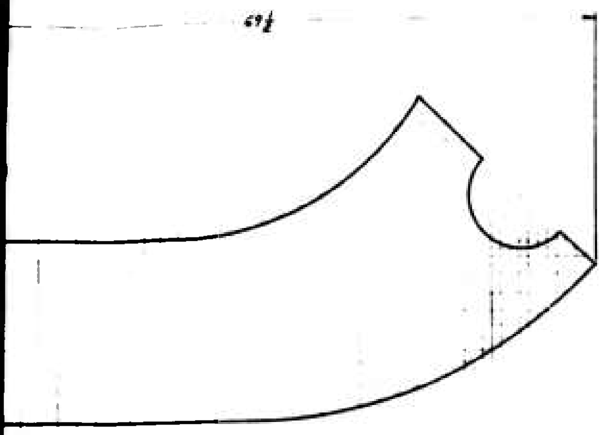


FRONT ELEVATION

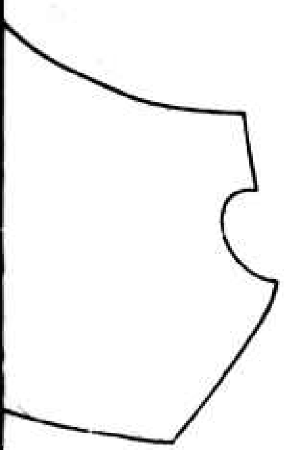


PROJECTED VIEW IN PLANE OF FORC

PART LIST						
ITEM	NO. REQ.	NAME OF PART	MAT'L	PIECES		REMARKS



PLAN VIEW



PLANE OF FORGING

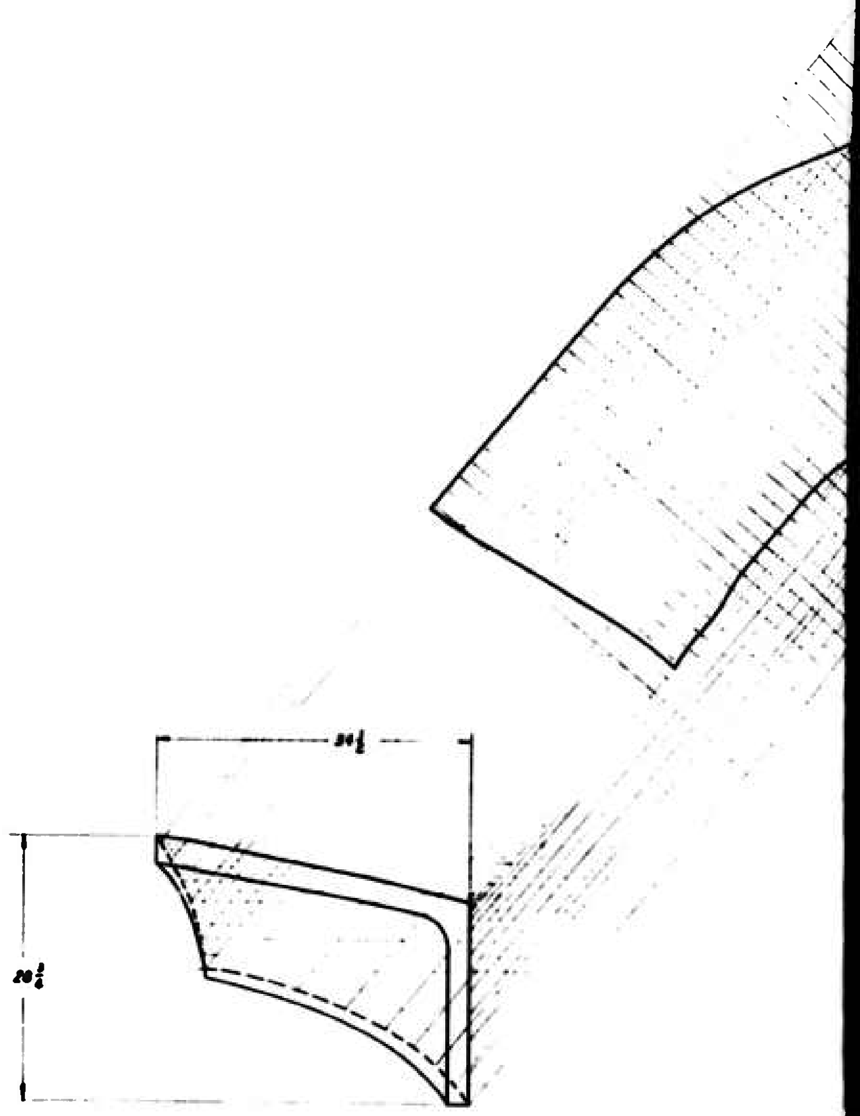
2

J-139

ENGINEERING SUPERVISION CO. 120 West 42nd St. New York, N. Y.	DRAWN BY M.J.P. DATE 8-4-48	M-48	
	DATE	TURRET - COMP. "B" LEFT FLANK PROJECTION	
TO REPLACE / REPLACED BY / ASSL. DWG.	APPROVED BY DATE WK	SCALE $1\frac{1}{2}$" - 1'-0"	DRAWING NUMBER 70-1138

SYM. NO.	DATE	REVISION		

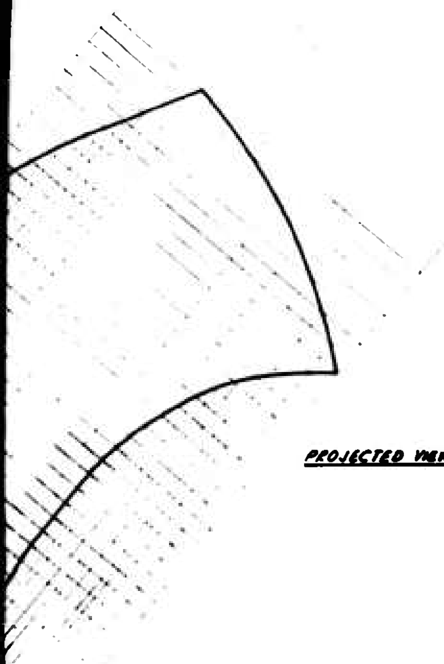
70-1139



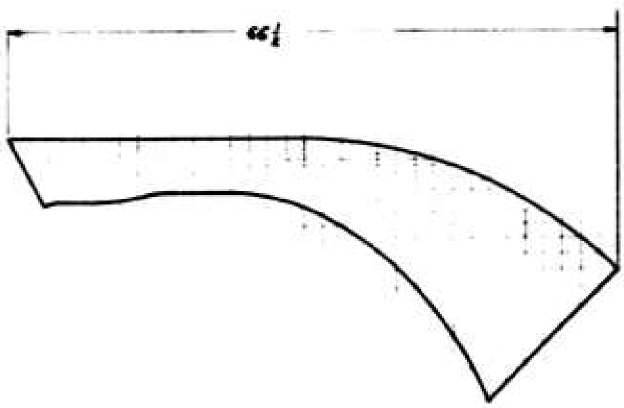
FRONT ELEVATION

1

PART LIST						
ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT.	TOTAL WT.	REMARKS



PROJECTED VIEW IN PLANE OF FORGING



PLAN VIEW

2

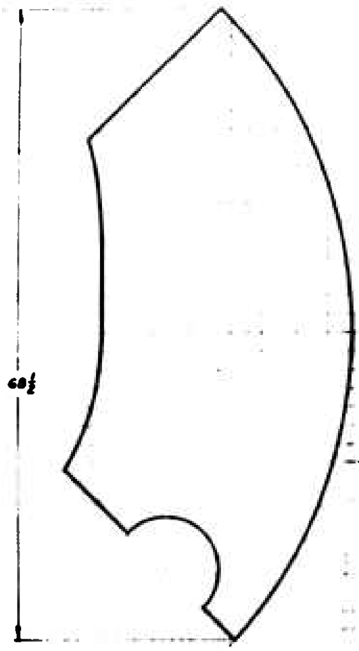
J-139

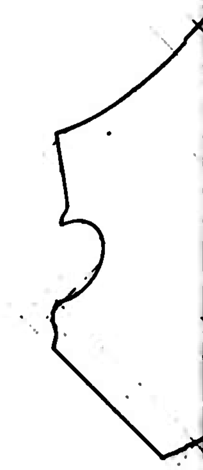
ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	DRAWN BY M.J.P DATE 8-4-00 CHECKED BY DATE	M-40
TO REPLACE / REPLACED BY / ASSOC. DWGS.	APPROVED BY WY DATE	TURRET-COMP 'B' RIGHT FLANK PROJECTION
		SCALE 1½"-1'-0" · DRAWING NUMBER 70-1139

REV. NO.	DATE	REVISION	BY	CHKD

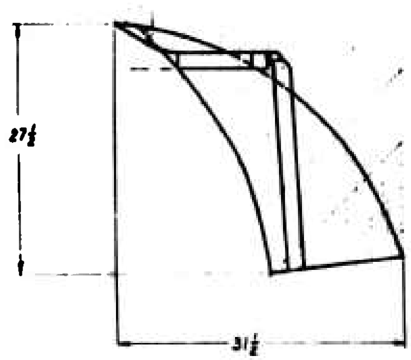
70-1140

PLAN VIEW





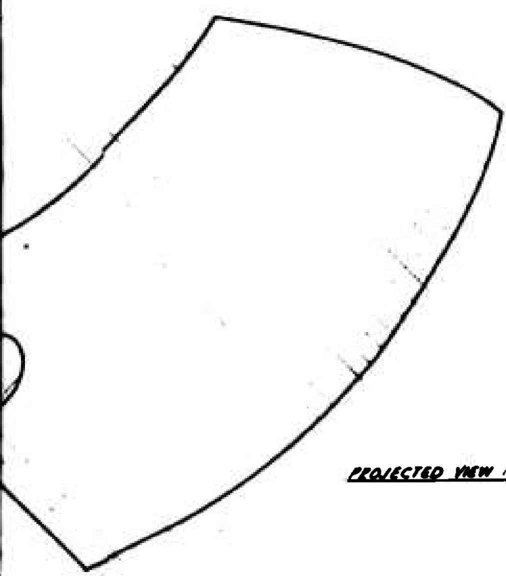
1



SIDE ELEVATION

PART LIST

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT.	FINISHED TOTAL WT.	REMARKS



PROJECTED VIEW IN PLANE OF FORGING

2

J-139

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

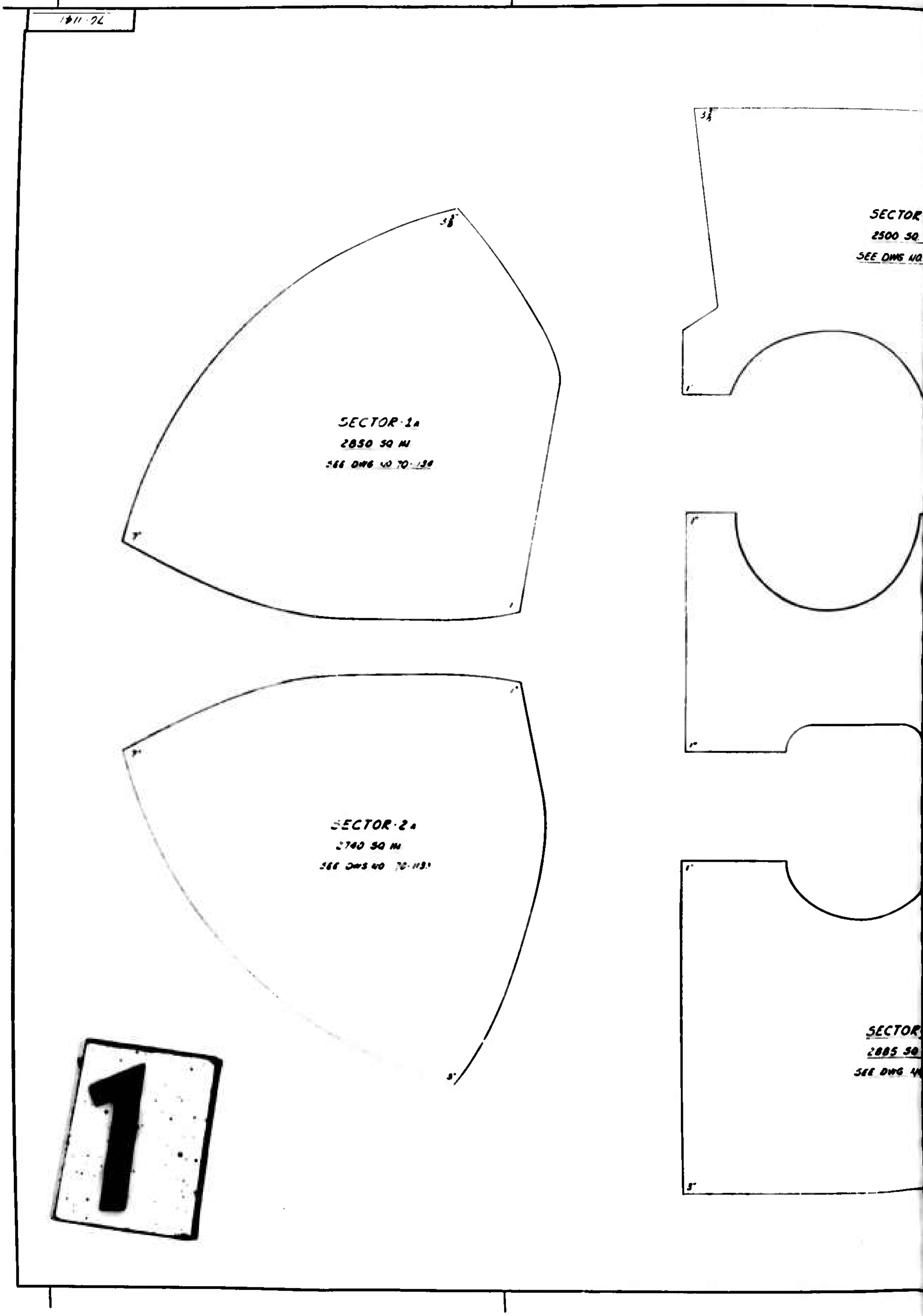
M-48

TURRET - COMP. 'B'
REAR PROJECTION

SCALE: 1½" = 1'-0"

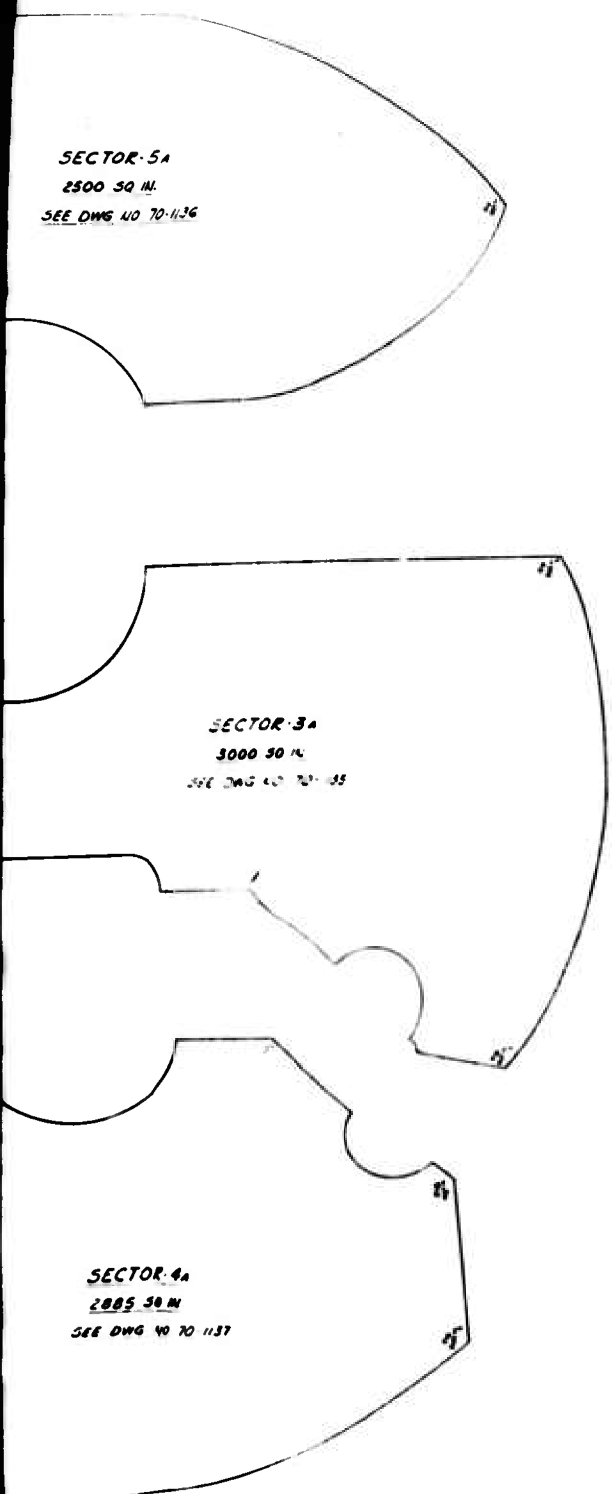
DRAWING NUMBER: 70-1140

REV. NO.	DATE	REVISION


SECTOR·1A
2850 SQ MI
SEE DWG NO 70-130
SECTOR·2A
2740 SQ MI
SEE DWG NO 70-113
SECTOR-
2500 SQ
SEE DWG NO
SECTOR
2885 SQ
SEE DWG N
1

PART LIST

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED	REMARKS

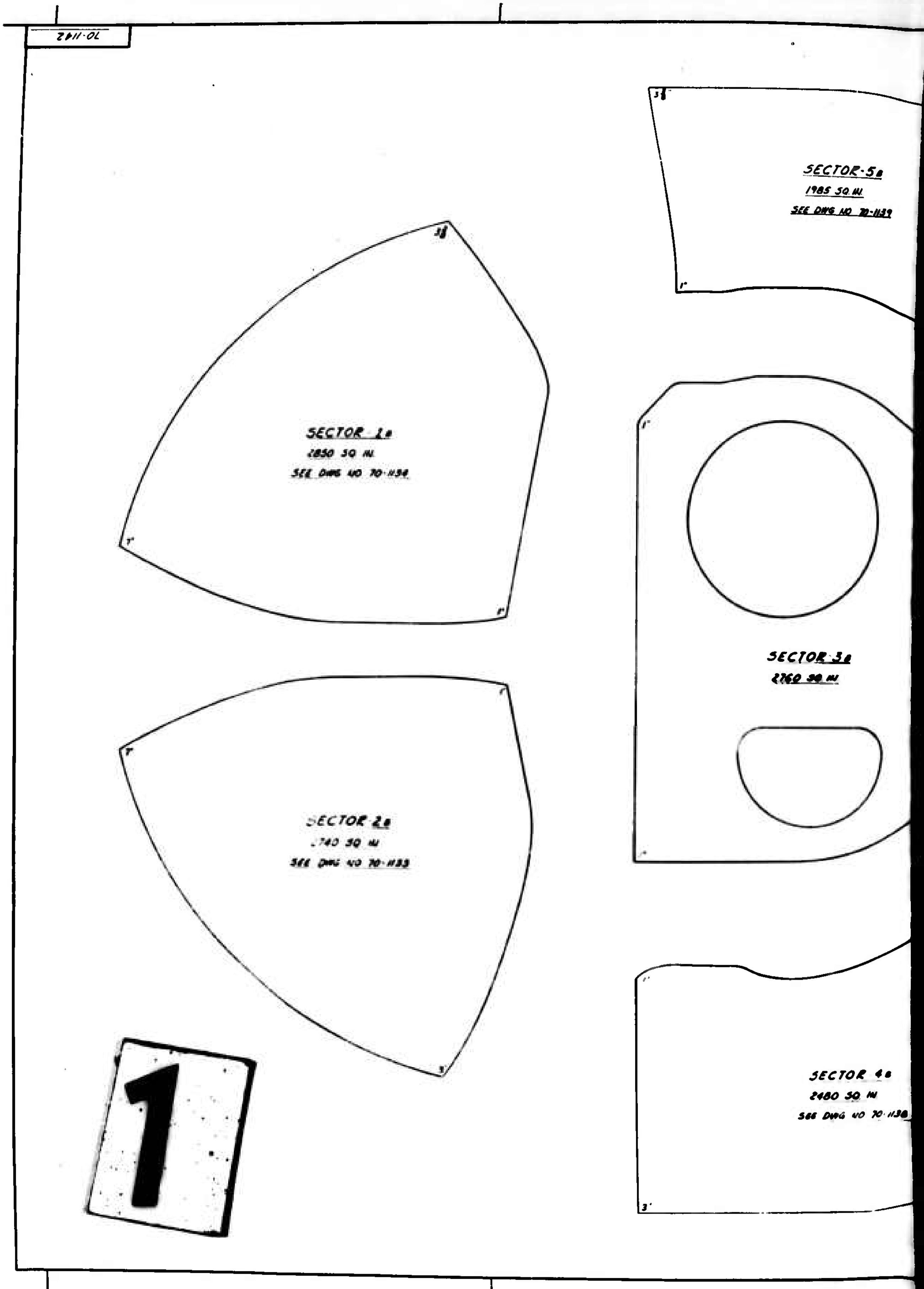


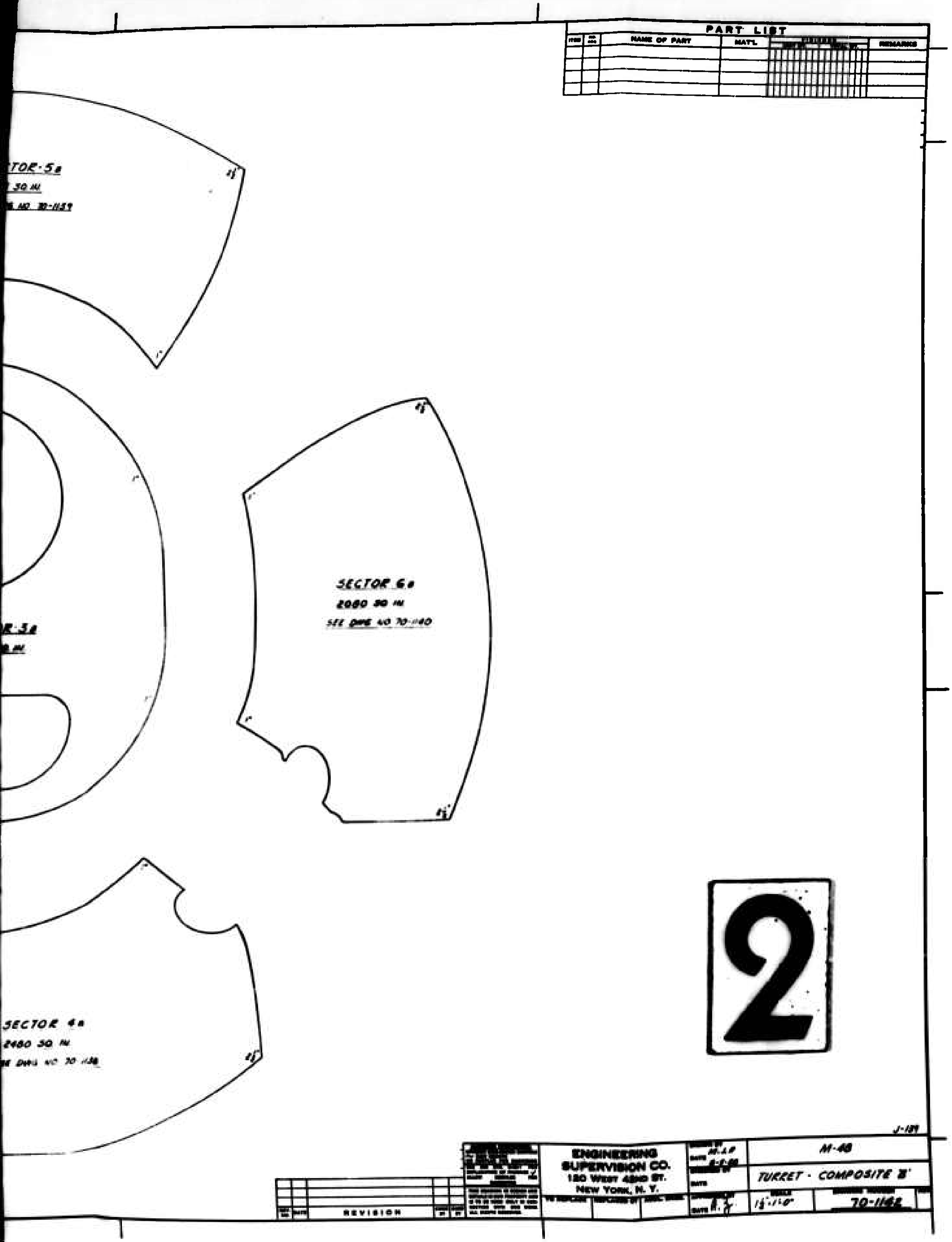
2

J-139

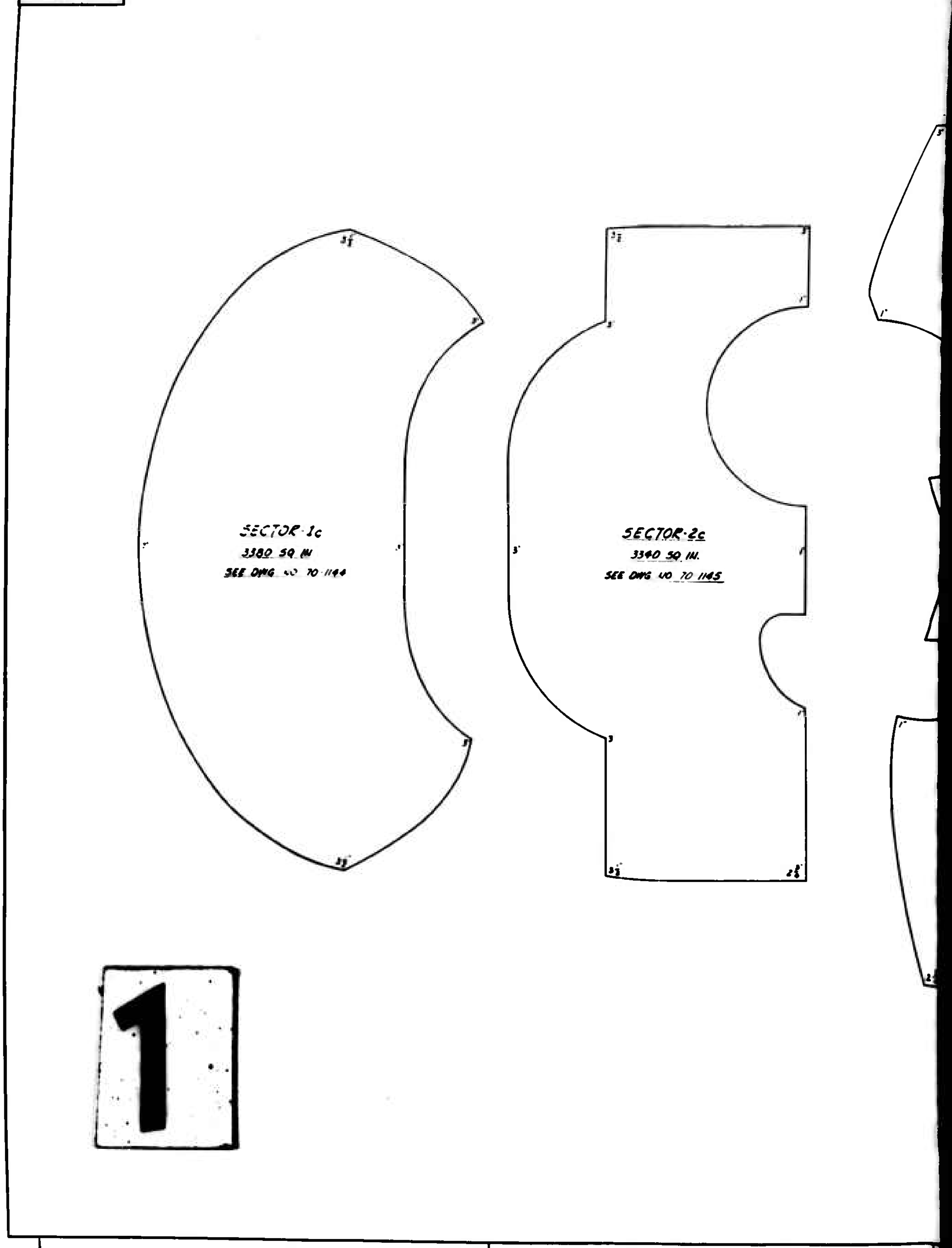
ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	M-48	
	TURRET - COMPOSITE 'A'	
DATE	SCALE 1½"-1'-0"	DRAWING NUMBER 70-1141

REVISION

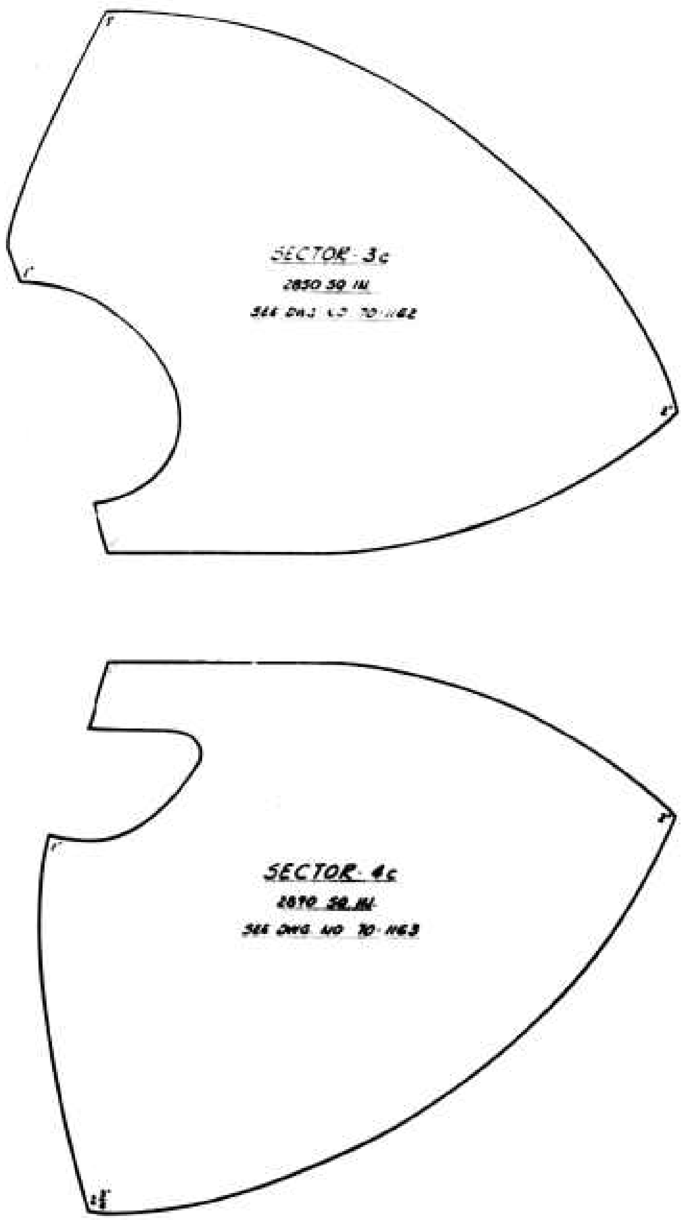

70-1142
SECTOR 1
2850 SQ IN
SEE DWG NO 70-1134
SECTOR 2
2740 SQ IN
SEE DWG NO 70-1133
SECTOR-5
1985 SQ. IN.
SEE DWG NO 70-1139
SECTOR 3
2760 SQ IN
SECTOR 4
2480 SQ IN
SEE DWG NO 70-1138
1


PART LIST
NAME OF PART
MAT'L
REMARKS
SECTOR 6a
2080 SQ IN
SEE DWG NO 70-1140
SECTOR 4a
2480 SQ IN
2
ENGINEERING SUPERVISION CO.
120 West 42nd St.
New York, N. Y.
M-48
TURRET - COMPOSITE 'B'
70-1142
REVISION

70-1143


SECTOR 1c
3380 SQ IN
SEE DWG NO 70 1144
SECTOR 2c
3340 SQ IN.
SEE DWG NO 70 1145
1

PART LIST						
ITEM	NO. REQ.	NAME OF PART	MAT'L	UNIT WT.	TOTAL WT.	REMARKS



2

J-139

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

DRAWN BY M.J.P.

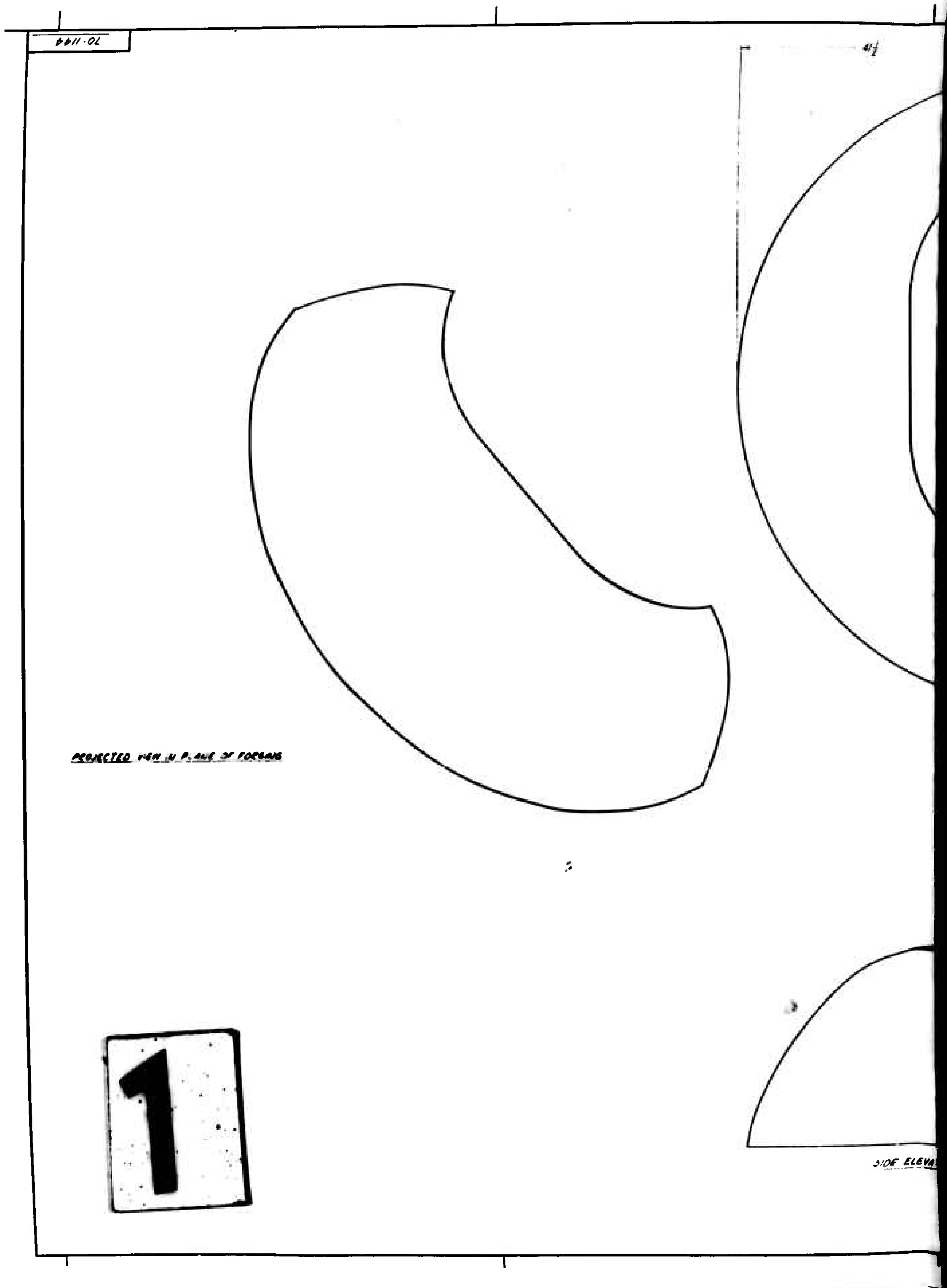
M-48

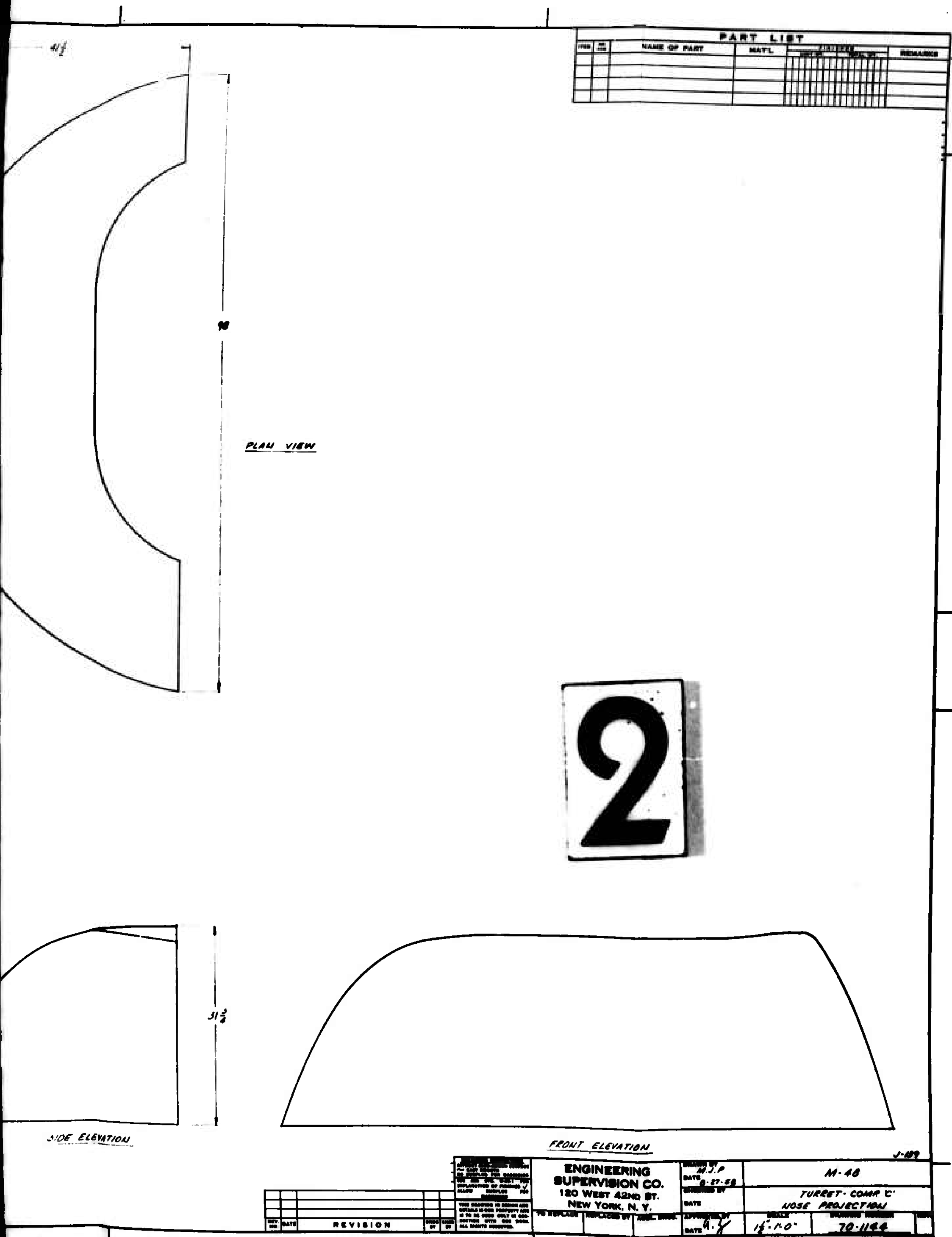
TURRET - COMPOSITE 'C'

SCALE $1\frac{1}{2}" = 1'0"$

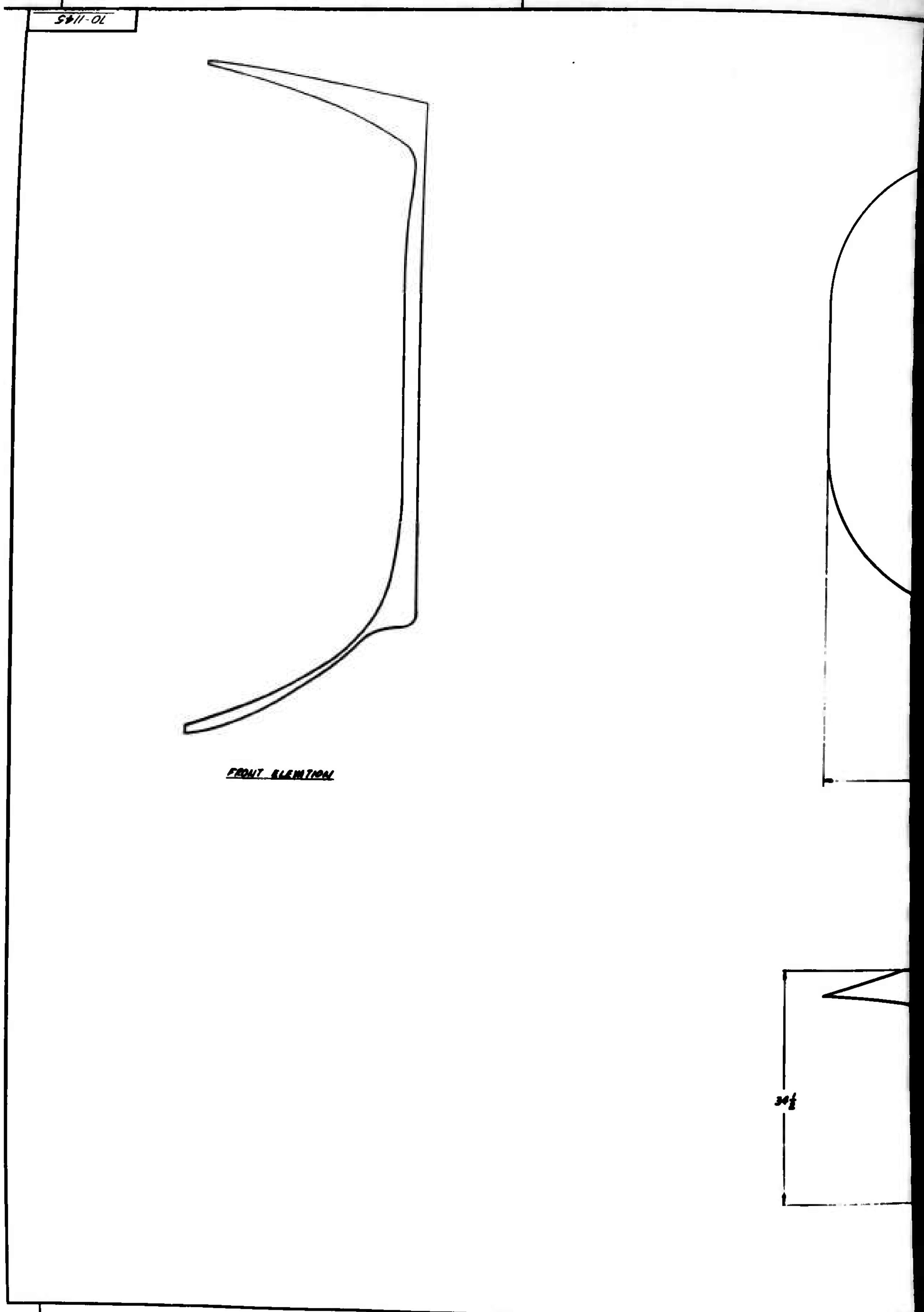
DRAWING NUMBER 70-1163

REVISION

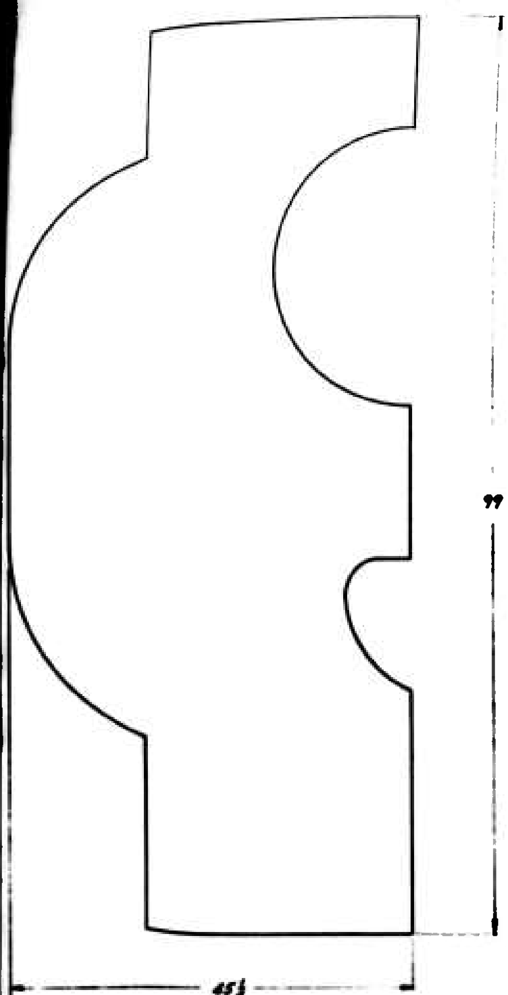

70-1144
41½
PROJECTED VIEW IN PLANE OF FORGING
SIDE ELEVA
1



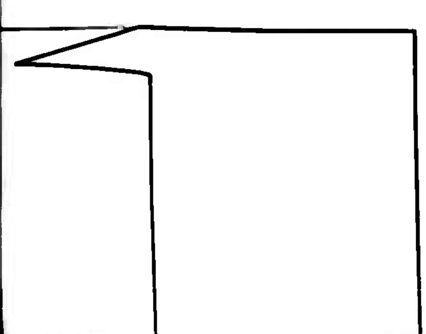
PART LIST
NAME OF PART
MAT'L
REMARKS
41 1/2
98
PLAN VIEW
31 3/4
SIDE ELEVATION
FRONT ELEVATION
2
J-189
REVISION
ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.
DRAWN BY M.J.P
DATE 8-27-58
CHECKED BY
DATE
APPROVED BY
DATE
TO REPLACE
REPLACED BY
M-48
TURRET - COMP 'C'
NOSE PROJECTION
SCALE
1 1/2"-1'-0"
DRAWING NUMBER
70-1144


70-1145
FRONT ELEVATION

PART LIST					
ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED UNIT WT. / TOTAL WT.	REMARKS



PLAN VIEW



SIDE ELEVATION

2

REV.	DATE	REVISION

J 29

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

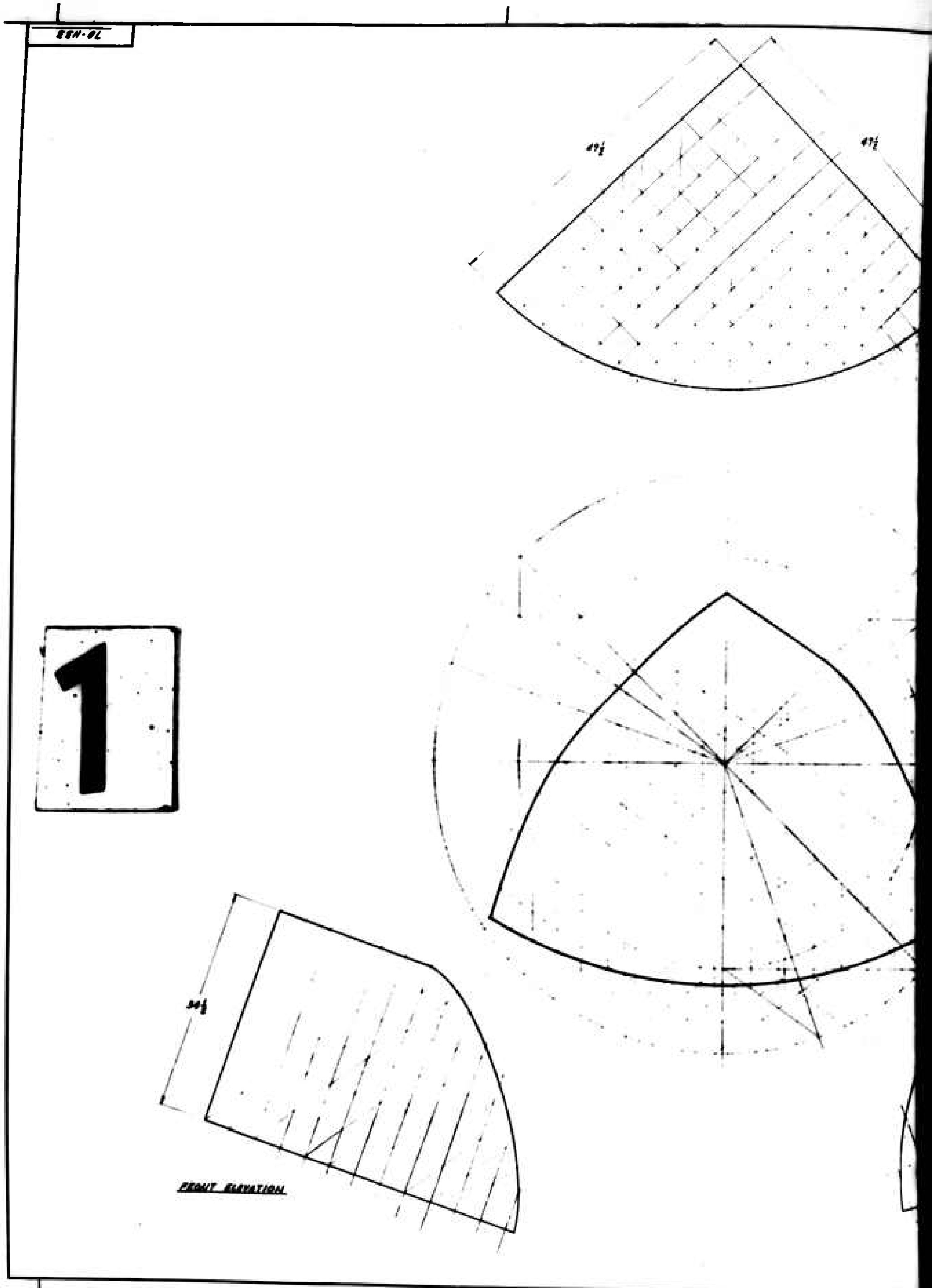
M.J.P.
DATE 2-17-48

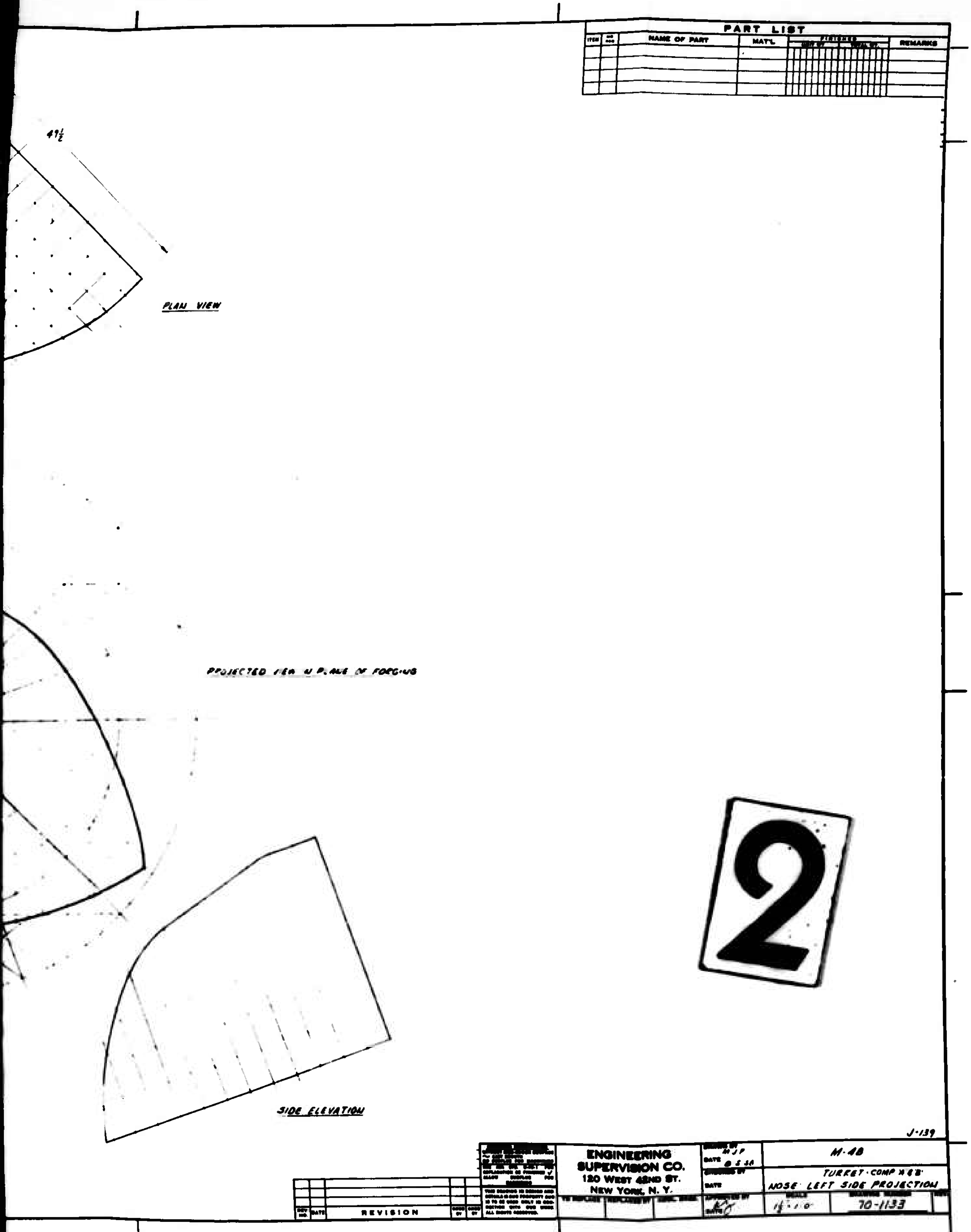
M-48

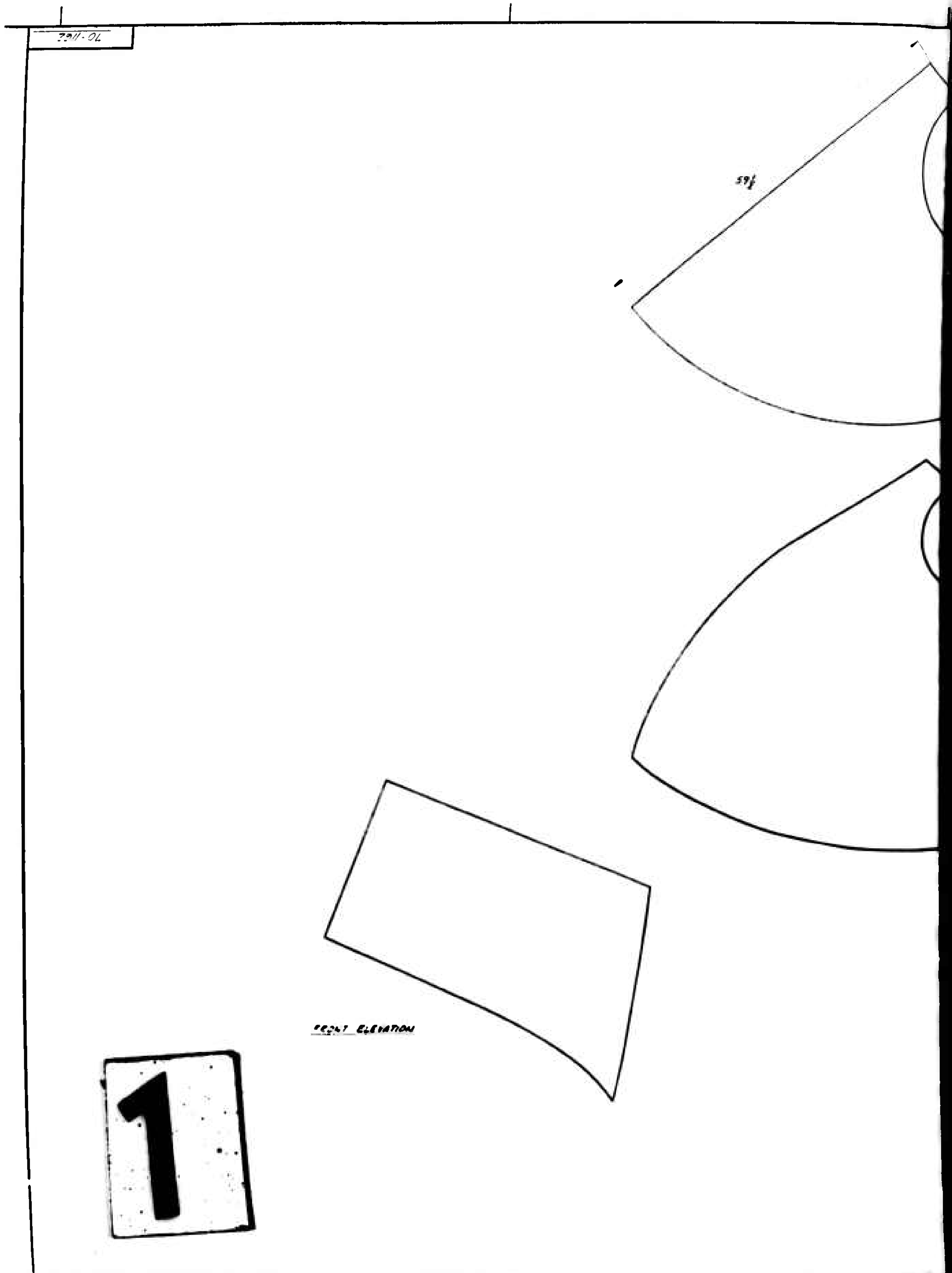
TURRET · COMP 'C'
CENTER SECTION

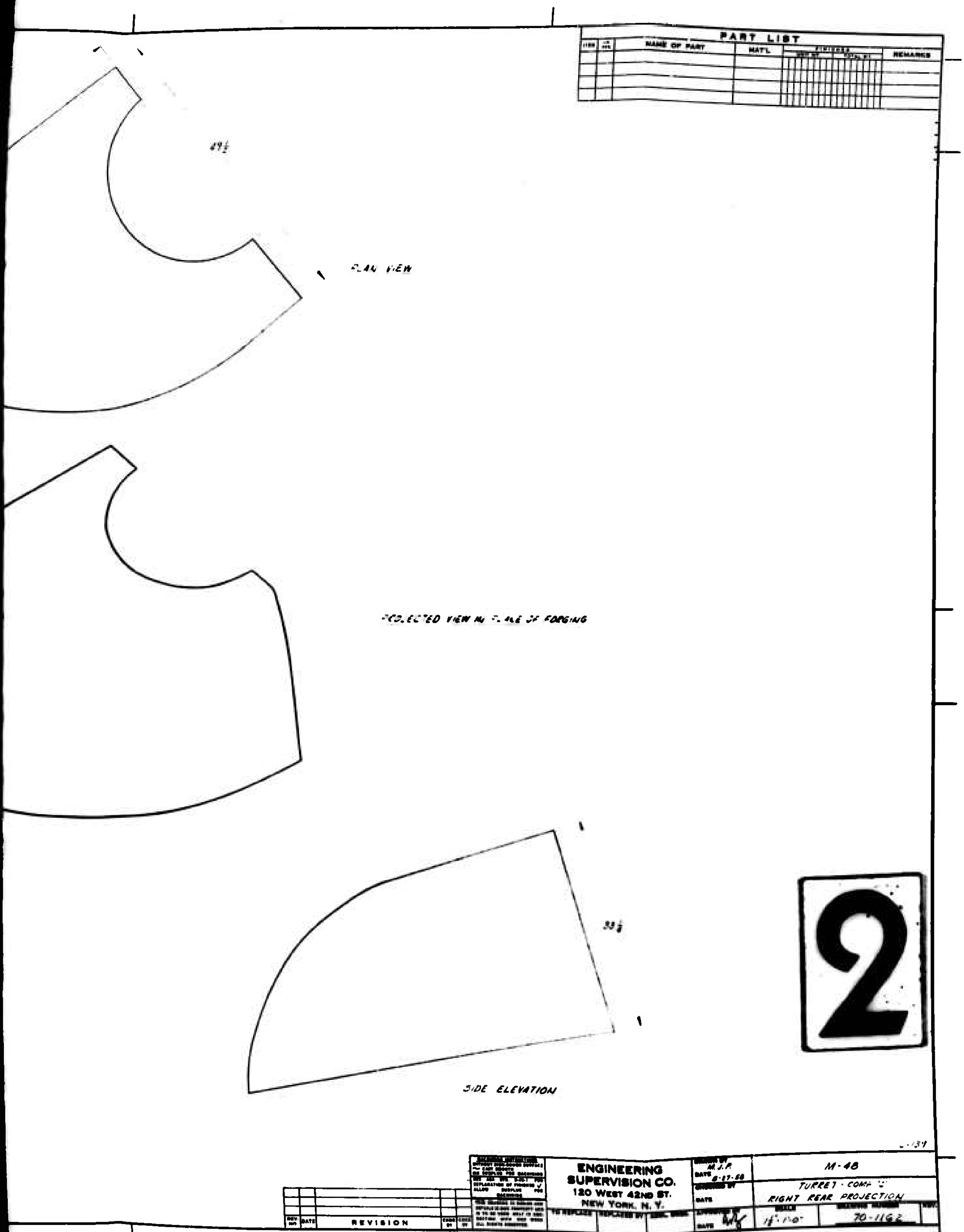
SCALE 1½"=1'0"

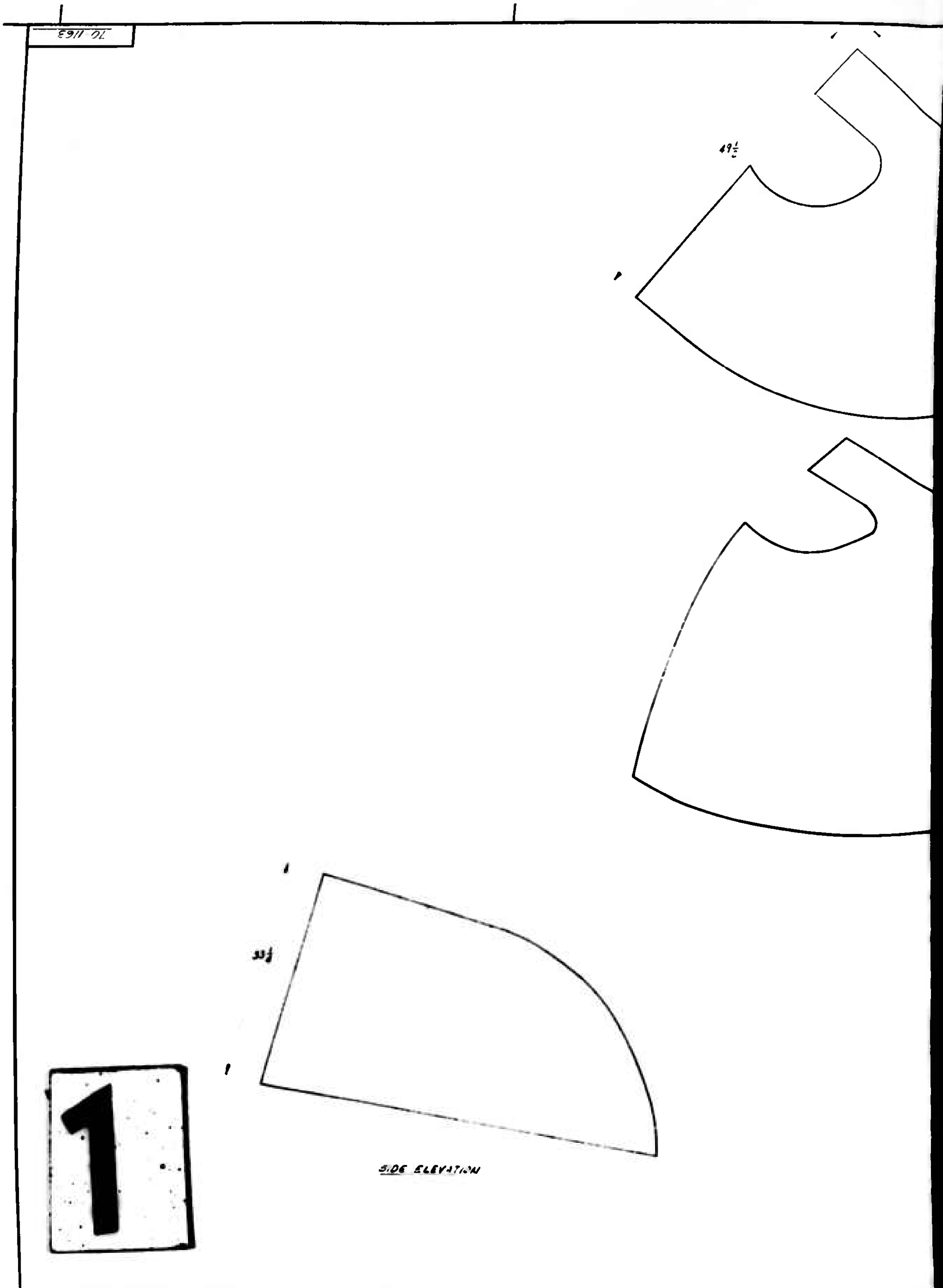
DRAWING NUMBER 70-1145


70-H83
1
49½
49½
34½
FRONT ELEVATION

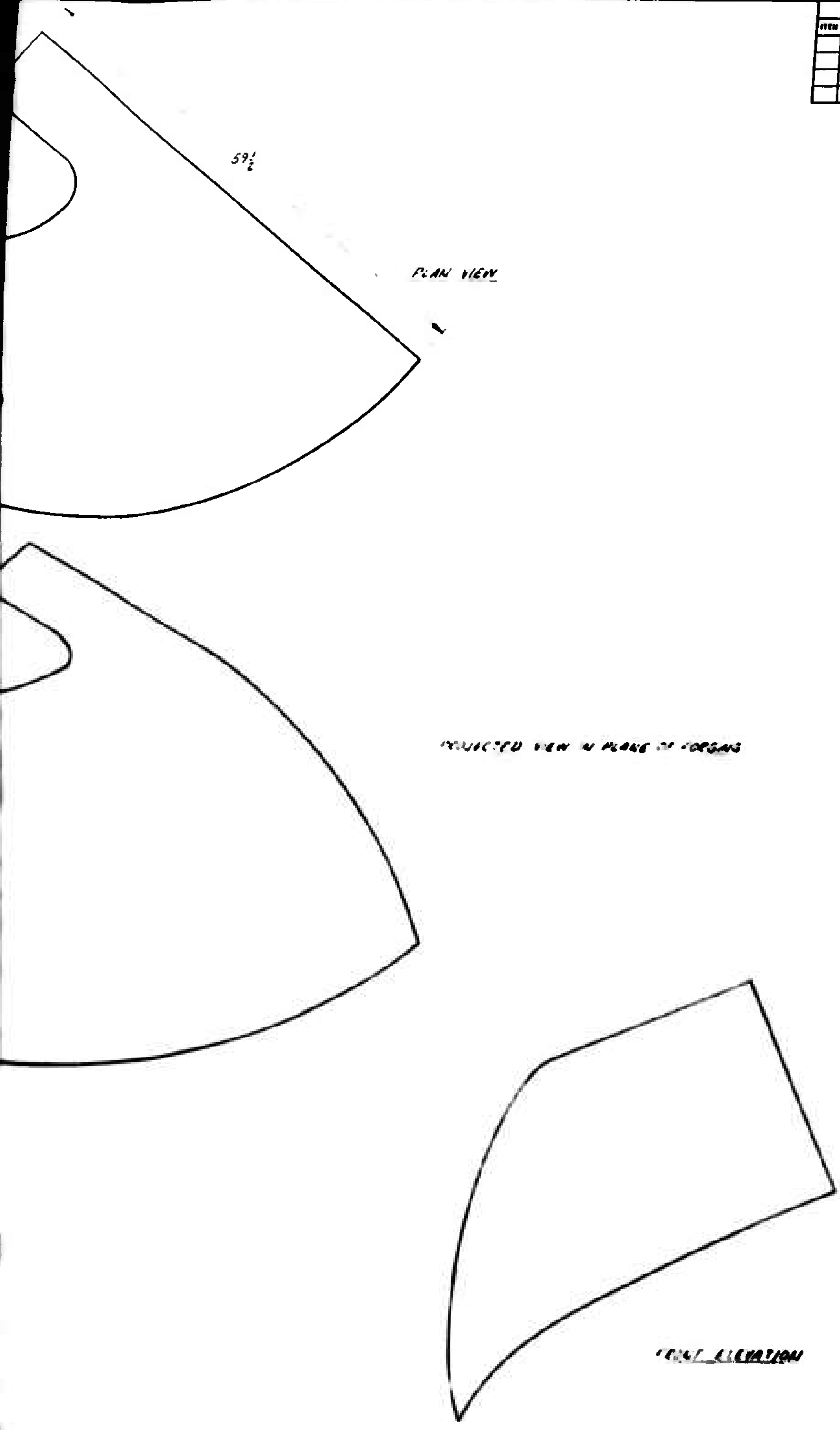

PART LIST
ITEM
NAME OF PART
MAT'L
FINISHES
REMARKS
$4\frac{1}{2}$
PLAN VIEW
PROJECTED VIEW IN PLANE OF FORCING
SIDE ELEVATION
2
J-139
REVISION
ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.
M J P
M-4B
TURRET - COMP "B"
NOSE - LEFT SIDE PROJECTION
70-1133
ALL RIGHTS RESERVED.


FRONT ELEVATION
1


PART LIST
NAME OF PART
MAT'L
REMARKS
PLAN VIEW
PROJECTED VIEW IN PLANE OF FORGING
SIDE ELEVATION
2
ENGINEERING
SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.
M.J.P.
DATE
REVISION
M-48
TURRET · COMP
RIGHT REAR PROJECTION
70-1162


49½
33¾
SIDE ELEVATION
1

PART LIST						
ITEM	NO. REQ	NAME OF PART	MAT'L	WEIGHT: UNIT WT.	TOTAL WT.	REMARKS



2

J-139

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

DRAWN BY	M.J.P
DATE	8-27-50
CHECKED BY	
DATE	
APPROVED BY	
DATE	

M-48

TURRET - COMP 'C'
LEFT REAR PROJECTION

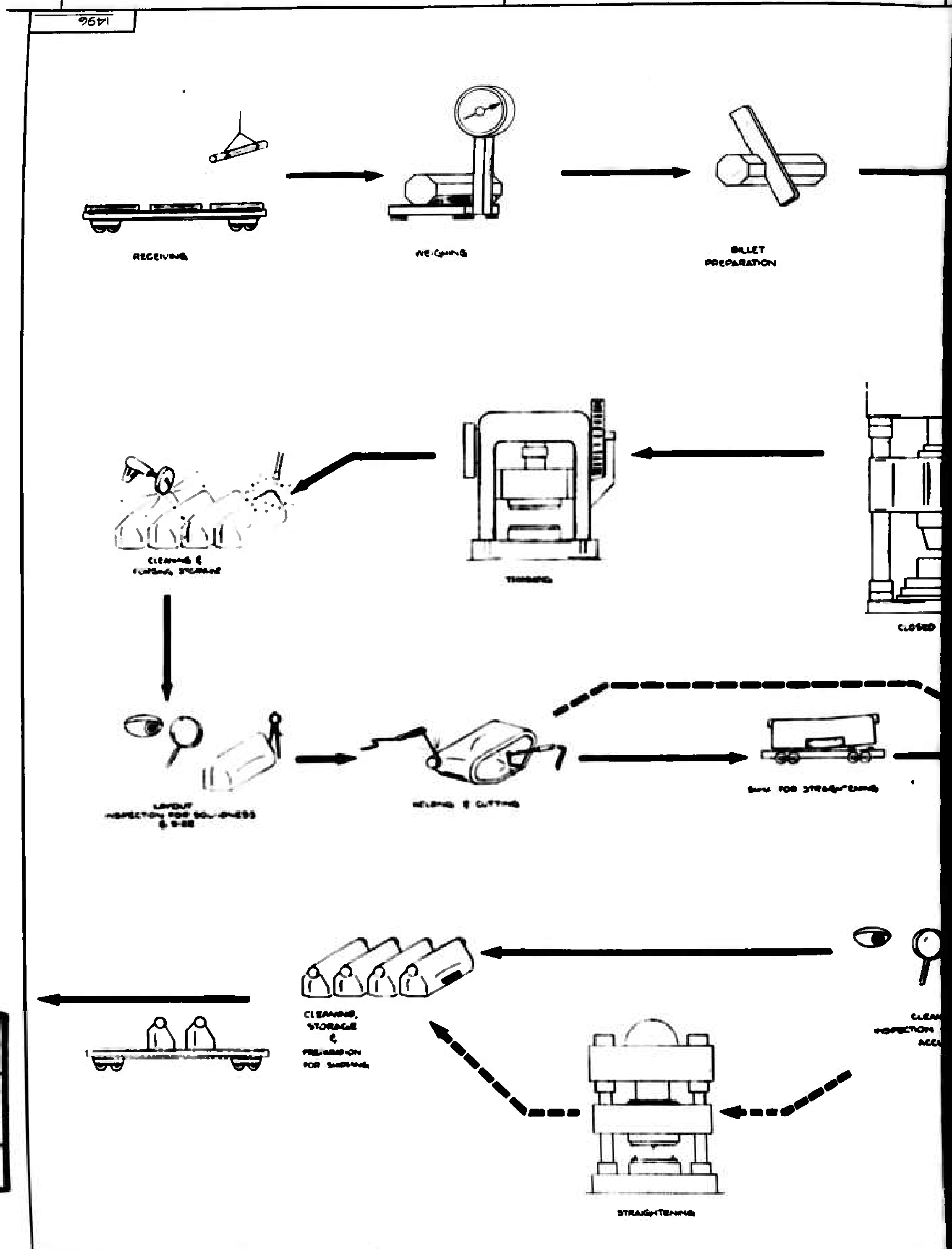
SCALE	DRAWING NUMBER
1½"=1'-0"	70-1163

REV. NO.	DATE	REVISION	CHKD BY	CHKD BY

Part

XXVIII **Material Flow**

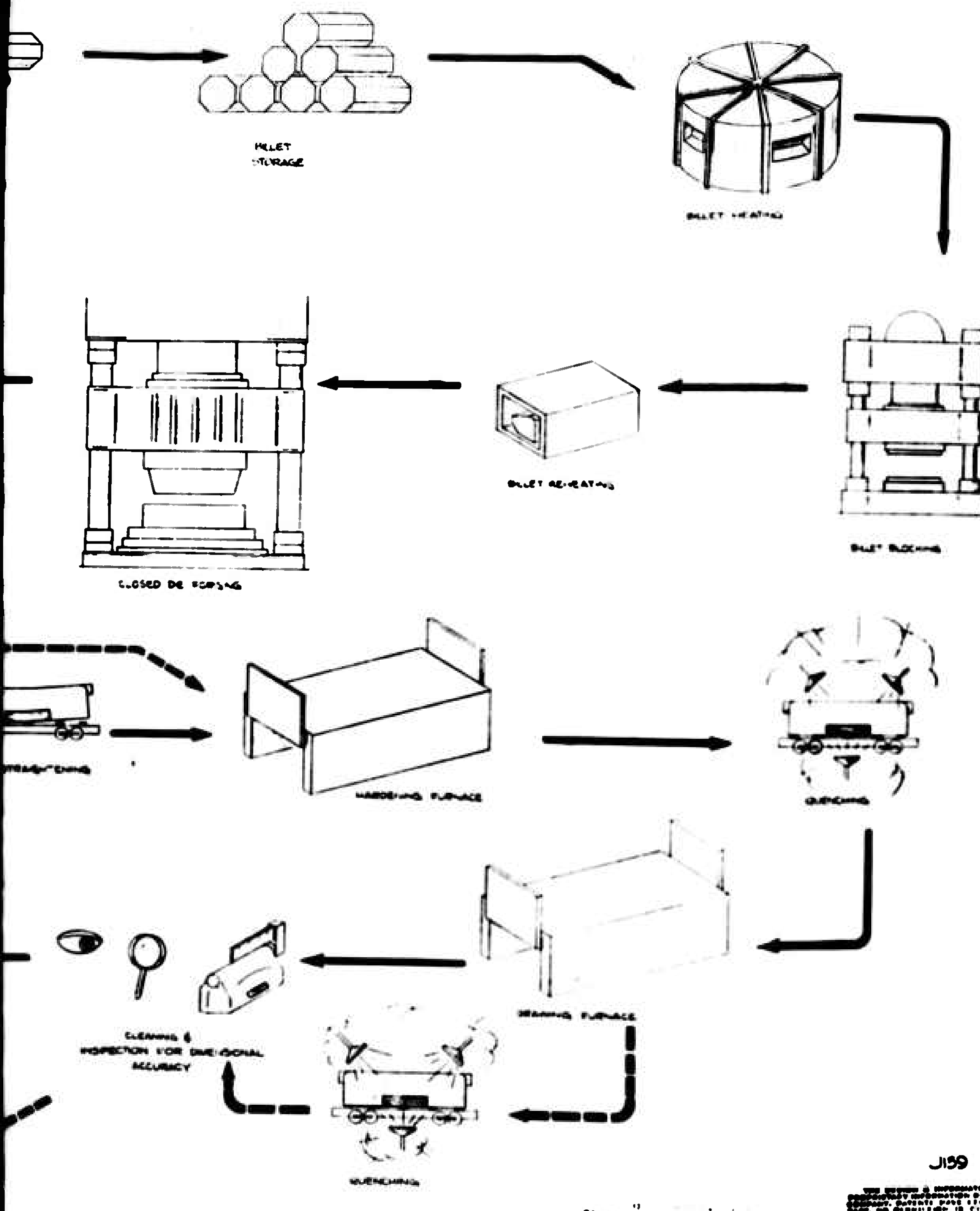
1496
1497
70-1131
70-1132


RECEIVING
WEIGHING
BILLET
PREPARATION
STRAIGHTENING
CLEANING,
STORAGE
&

1

ITEM	NO. REQ.	NAME OF PART	MAT'L	FINISHED		REMARKS

PART LIST



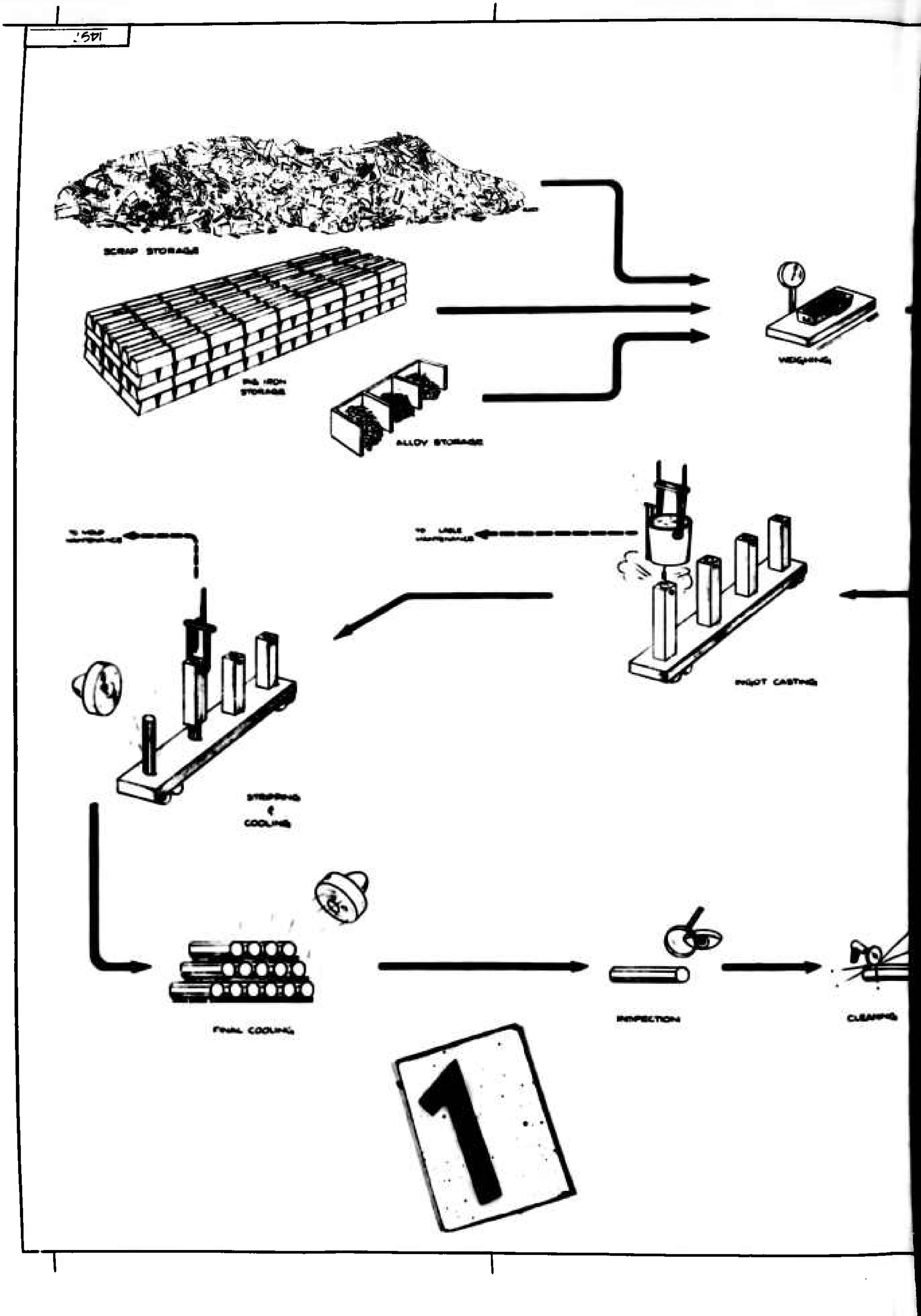
J159

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

PROCESS FLOW CHART
FOR FORGING
TANK HULL FRONTS

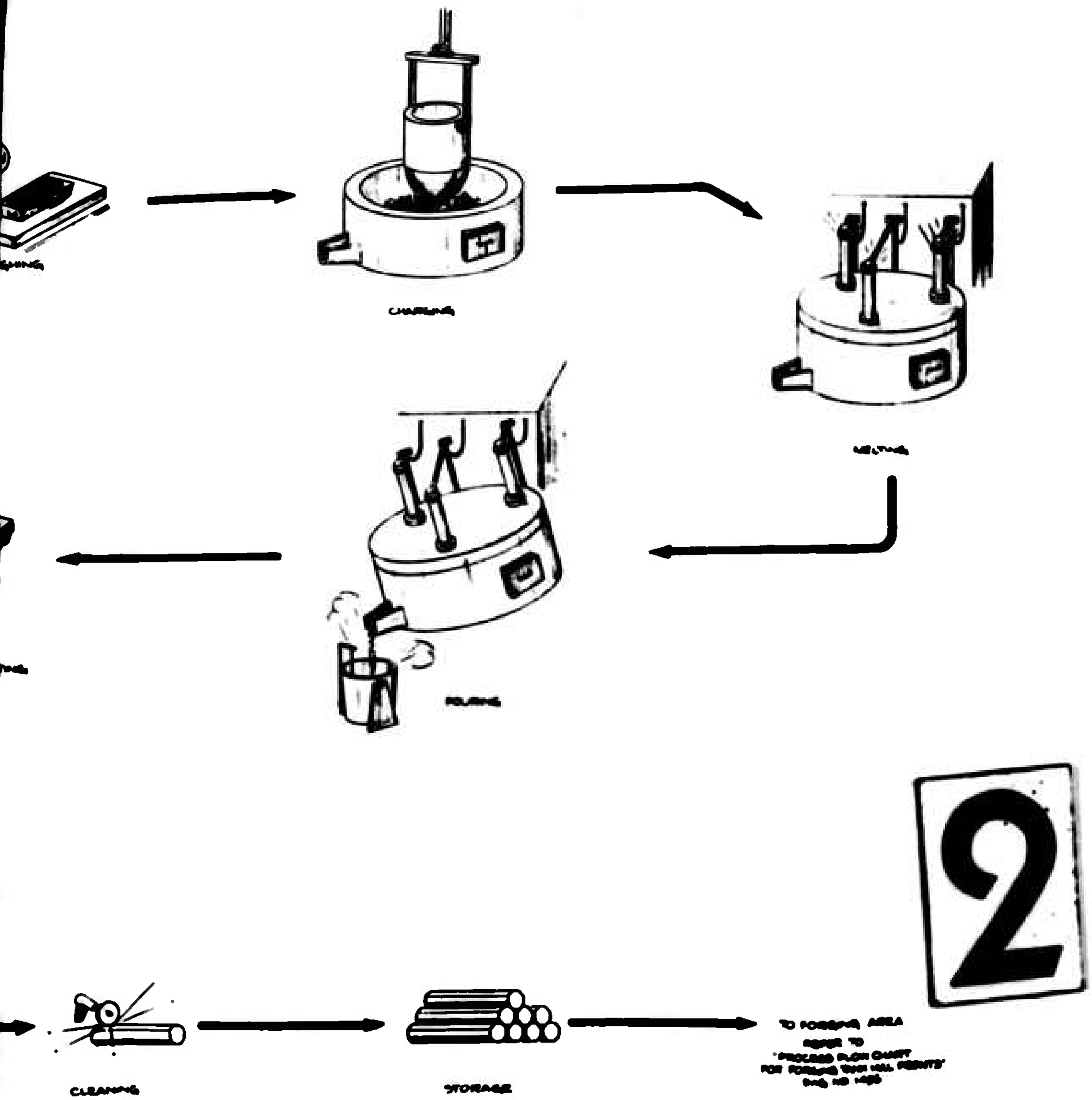
1496

2


SCRAP STORAGE
PIG IRON STORAGE
ALLOY STORAGE
WEIGHING
INGOT CASTING
STRIPPING
&
COOLING
FINAL COOLING
INSPECTION
CLEANING
1

PART LIST

ITEM		NAME OF PART	MAT'L			REMARKS

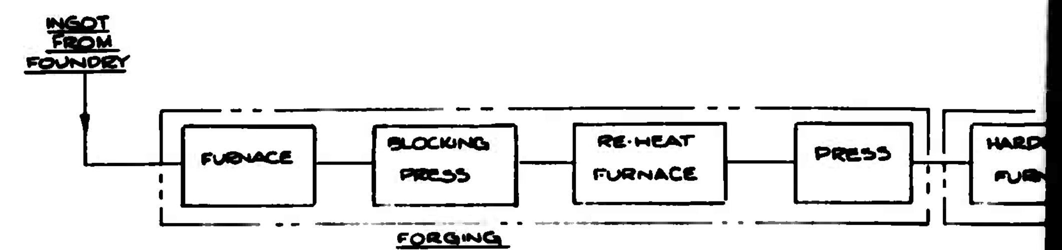


J-139

ENGINEERING SUPERVISION CO. 120 WEST 42ND ST. NEW YORK, N. Y.	PROCESS FLOW CHART FOR INGOT CASTING FACILITY
	1497

REVISION

C-70-1191



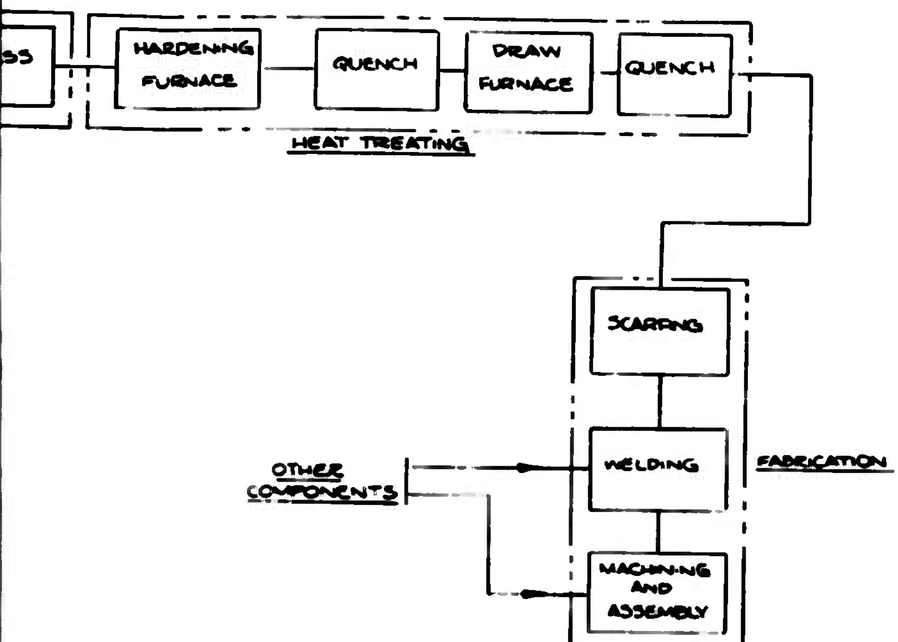
NOTE: ANY INDIVIDUAL COMPONENT MAY REQUIRE MORE THAN ONE (1) BLOCKING OPERATIO

1

REV. NO.	DATE	REVISION

PART LIST

ITEM	NO. REQ	NAME OF PART	MAT'L	FINISHED UNIT WT.	FINISHED TOTAL WT.	REMARKS



NG OPERATION.

J-159

EVISION | CHKD BY | CHKD BY

[illegible] SURFACE ~ CAST SMOOTH NO SURPLUS FOR MACHINING

USE ASA STD. B46-1 FOR EXPLANATION OF FINISHES ✓ ALLOW SURPLUS FOR MACHINING

ENGINEERING SUPERVISION CO.
743 FIFTH AVE.
NEW YORK, U.S.A.

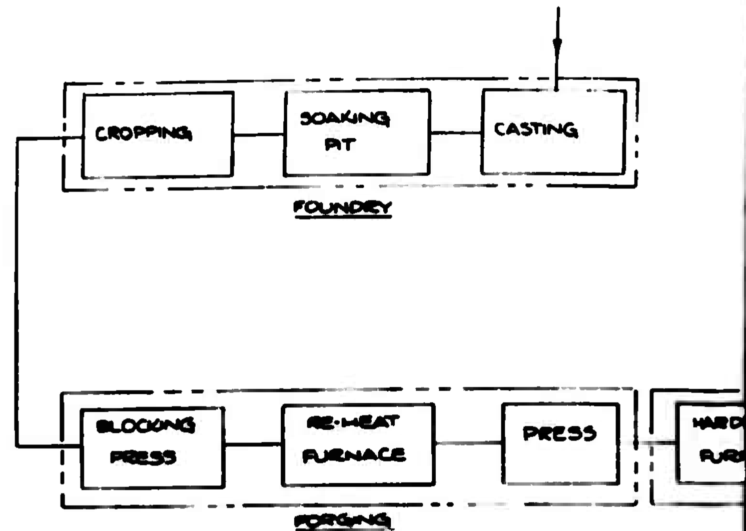
TO REPLACE | REPLACED BY | ADDL. DRGS.

DRAWN BY GES
DATE 6-18-58
CHECKED BY
DATE
APPROVED BY
DATE

TYPICAL FLOW SHEET FOR FORGED COMPONENTS

SCALE ——
DRAWING NUMBER C-70-1131
REV.

C-70-1132



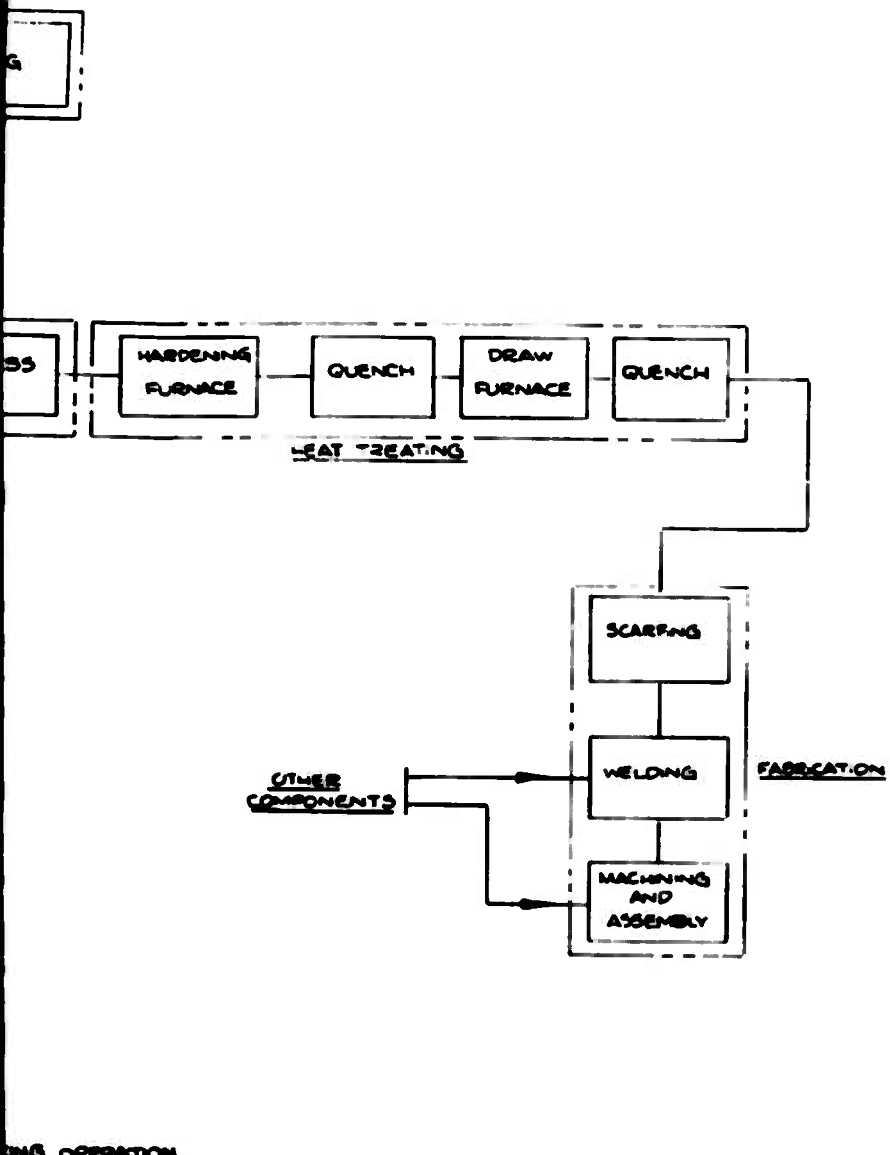
NOTE: ANY INDIVIDUAL COMPONENT MAY REQUIRE MORE THAN ONE (1) BLOCKING OPERATION

REV. NO.	DATE	REVISION

1

PART LIST

ITEM	NO. REQ	NAME OF PART	MAT'L	FINISHES UNIT WT.	FINISHES TOTAL WT.	REMARKS



J-139

ENGINEERING SUPERVISION CO. 743 FIFTH AVE. NEW YORK, U.S.A.	DRAWN BY	DATE 6-18-58	TYPICAL FLOW SHEET FOR FORGED COMPONENTS
	CHECKED BY	DATE	
TO REPLACE	REPLACED BY	ADDL. DRGS.	APPROVED BY / DATE
SCALE	DRAWING NUMBER C-70-1152	REV.	

REVISION

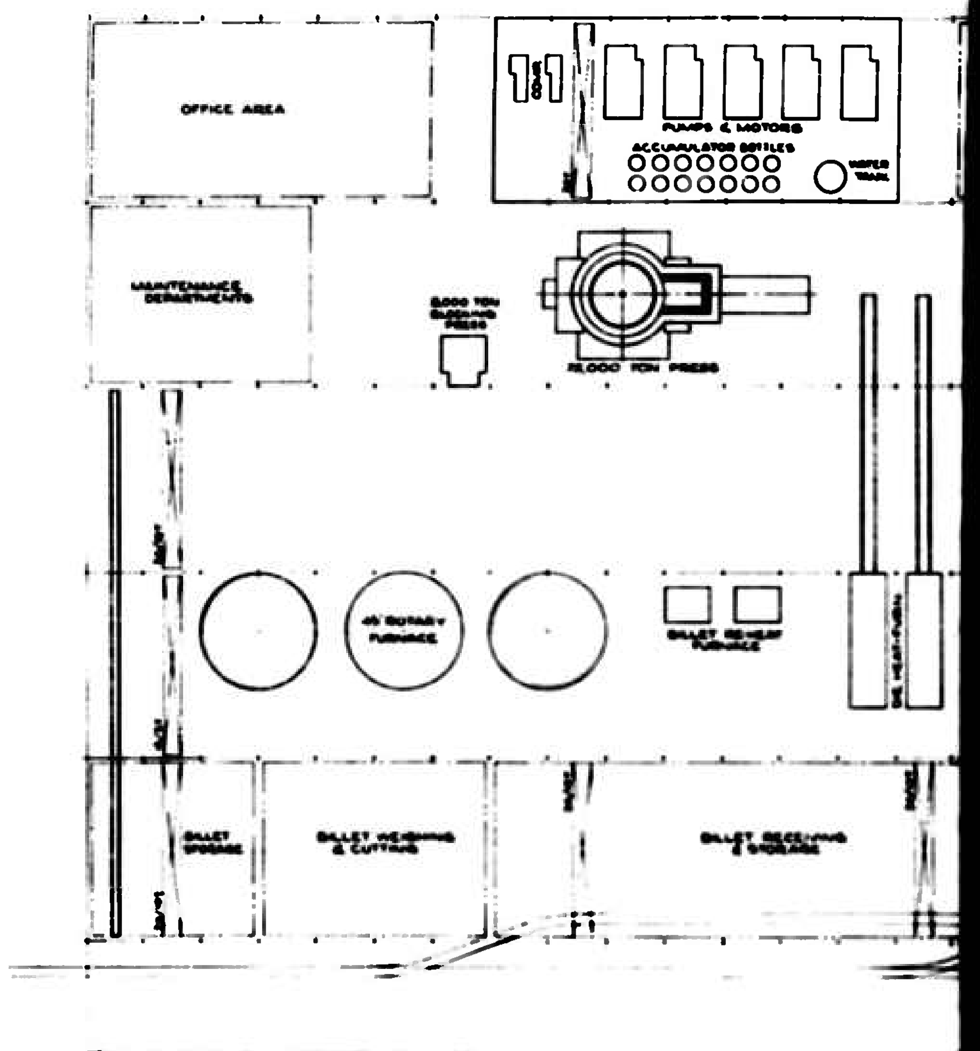
2

Part

XXIX Plant Layouts

1498
1499
1500
1517

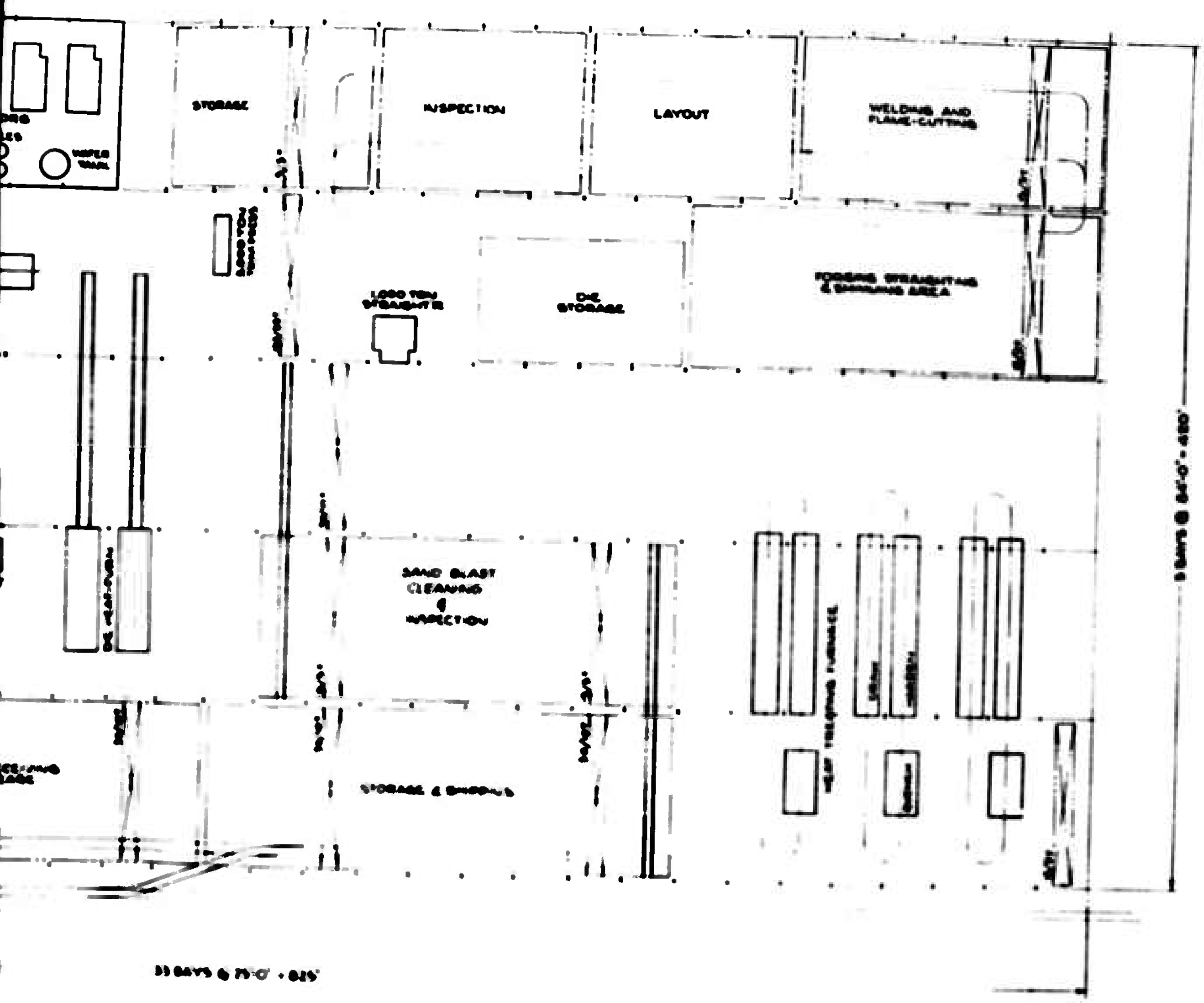
1498



OFFICE AREA
PUMPS & MOTORS
ACCUMULATOR BOTTLES
WATER TANK
MAINTENANCE DEPARTMENTS
TON PRESS
BILLET REHEAT FURNACE
BILLET STORAGE
BILLET WEIGHING & CUTTING
BILLET RECEIVING & STORAGE

1

PART LIST						
ITEM		NAME OF PART	MAT'L			REMARKS



2

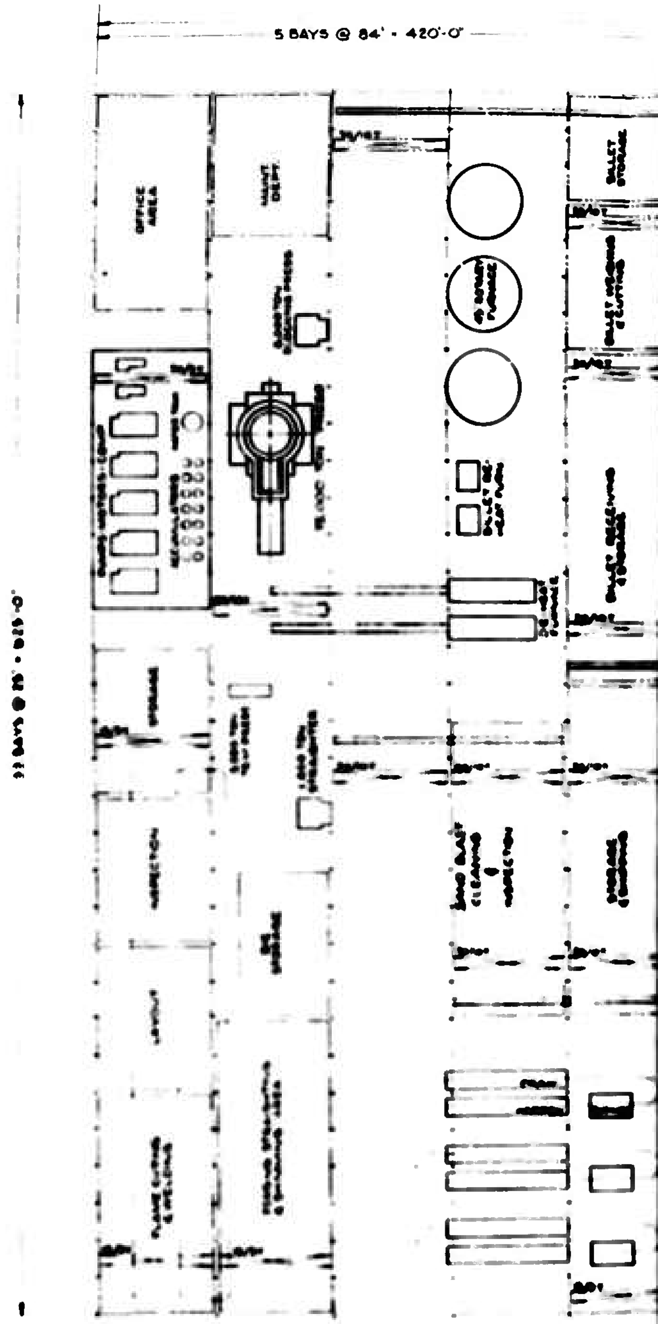
J-180

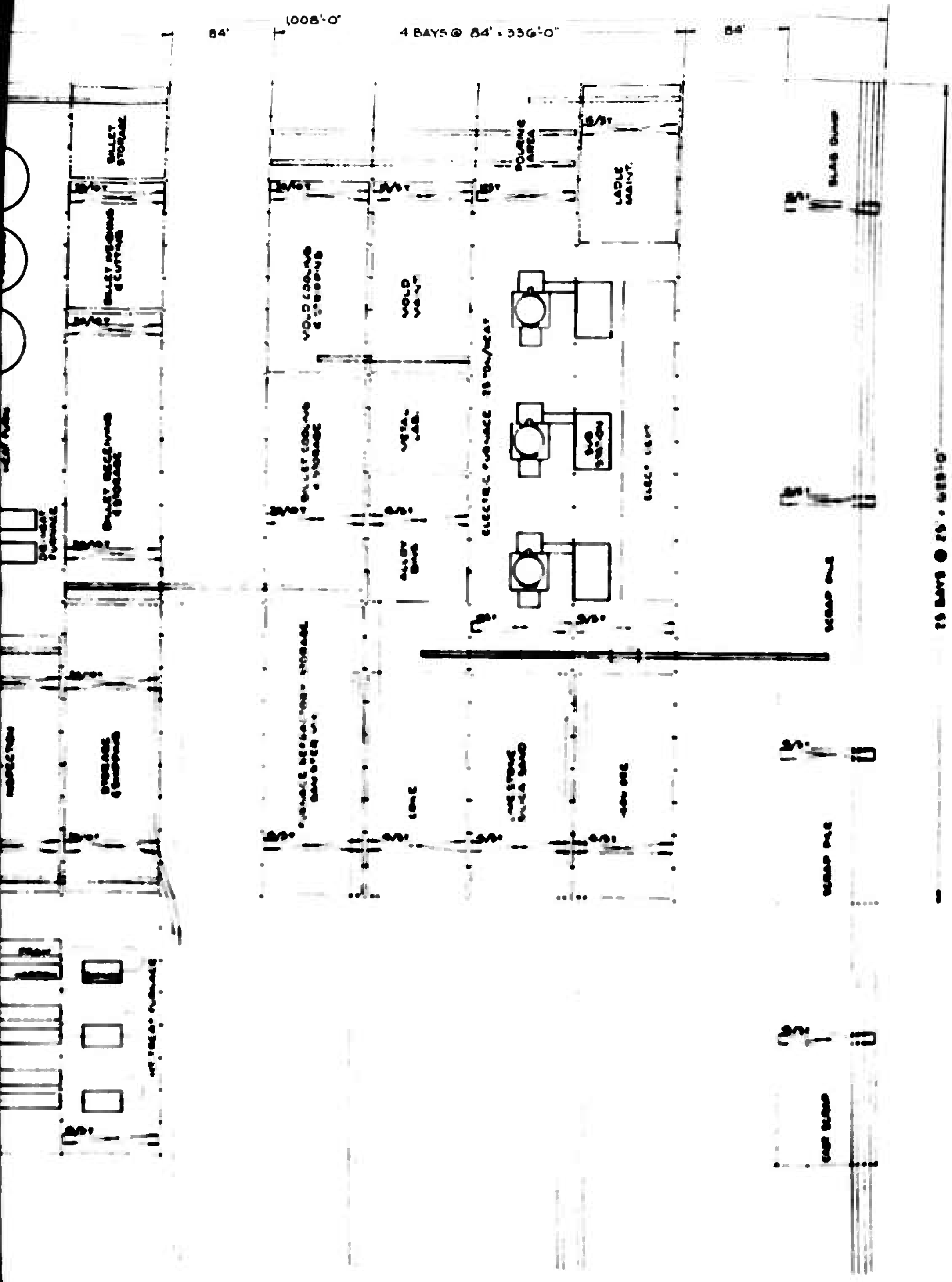
UNLESS OTHERWISE SPECIFIED

ENGINEERING SUPERVISION CO. NEW YORK, N. Y.	4-14-50	PLANT LAYOUT	
		ISOLATED FORGING PLANT FOR TANK-HULL FRONTS	
1492		1/32" = 1'-0"	1498

REVISION

1499





PART LIST

ITEM	NO.	NAME OF PART	MAT'L		REMARKS

J-150

UNLESS OTHERWISE STATED
TOLERANCE ... DIMENSIONS
BREAK ALL SHARP CORNERS AND CAREFULLY DEBURR

REV.	DATE	REVISION	BY	

ENGINEERING SUPERVISION CO.
120 WEST 42ND ST.
NEW YORK, N. Y.

DATE 4-17-50

PLANT LAYOUT

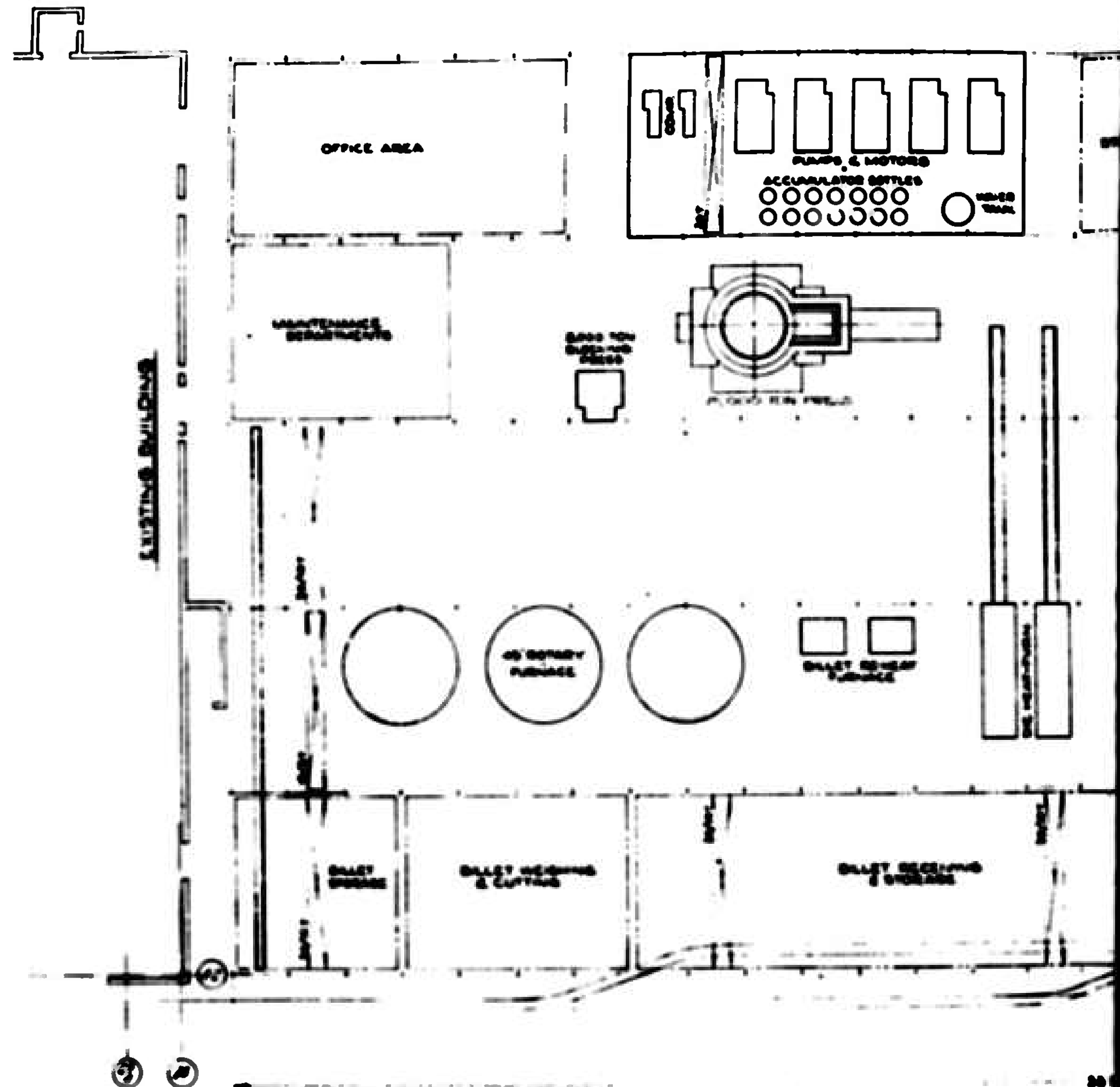
CASTING & FORGING FACILITIES FOR TANK-HULL FRONTS

1493

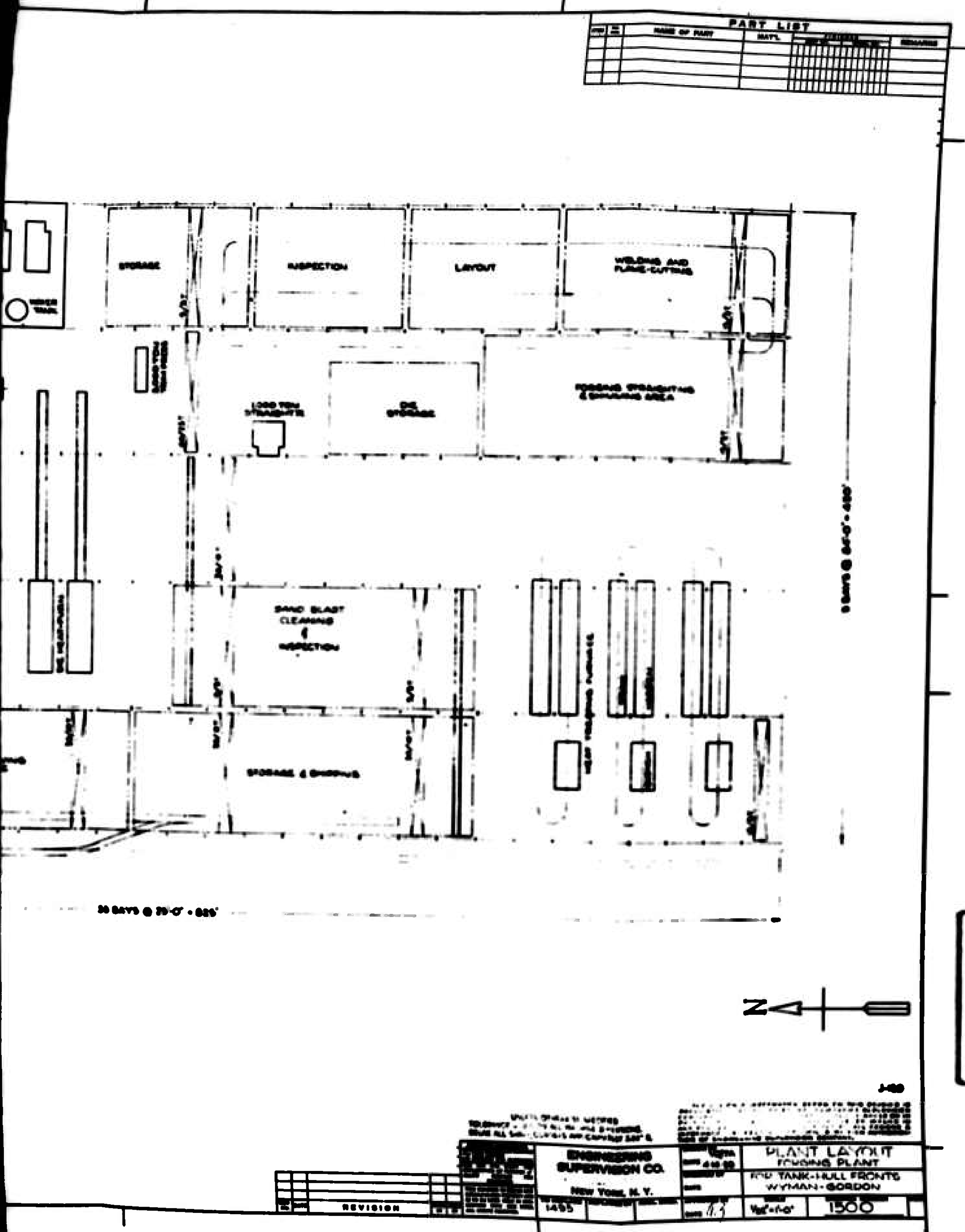
SCALE 1" = 30'

1499

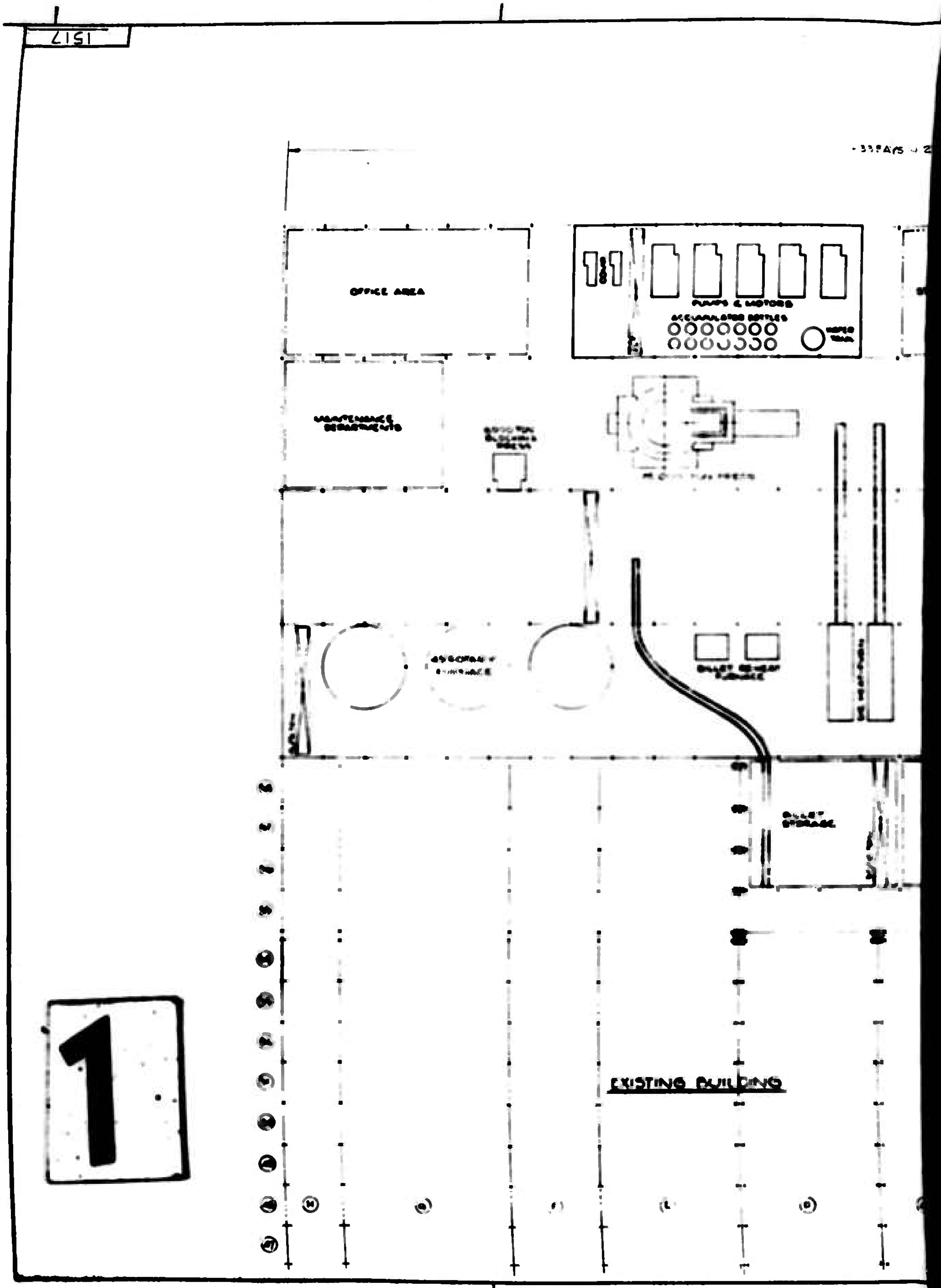
1500

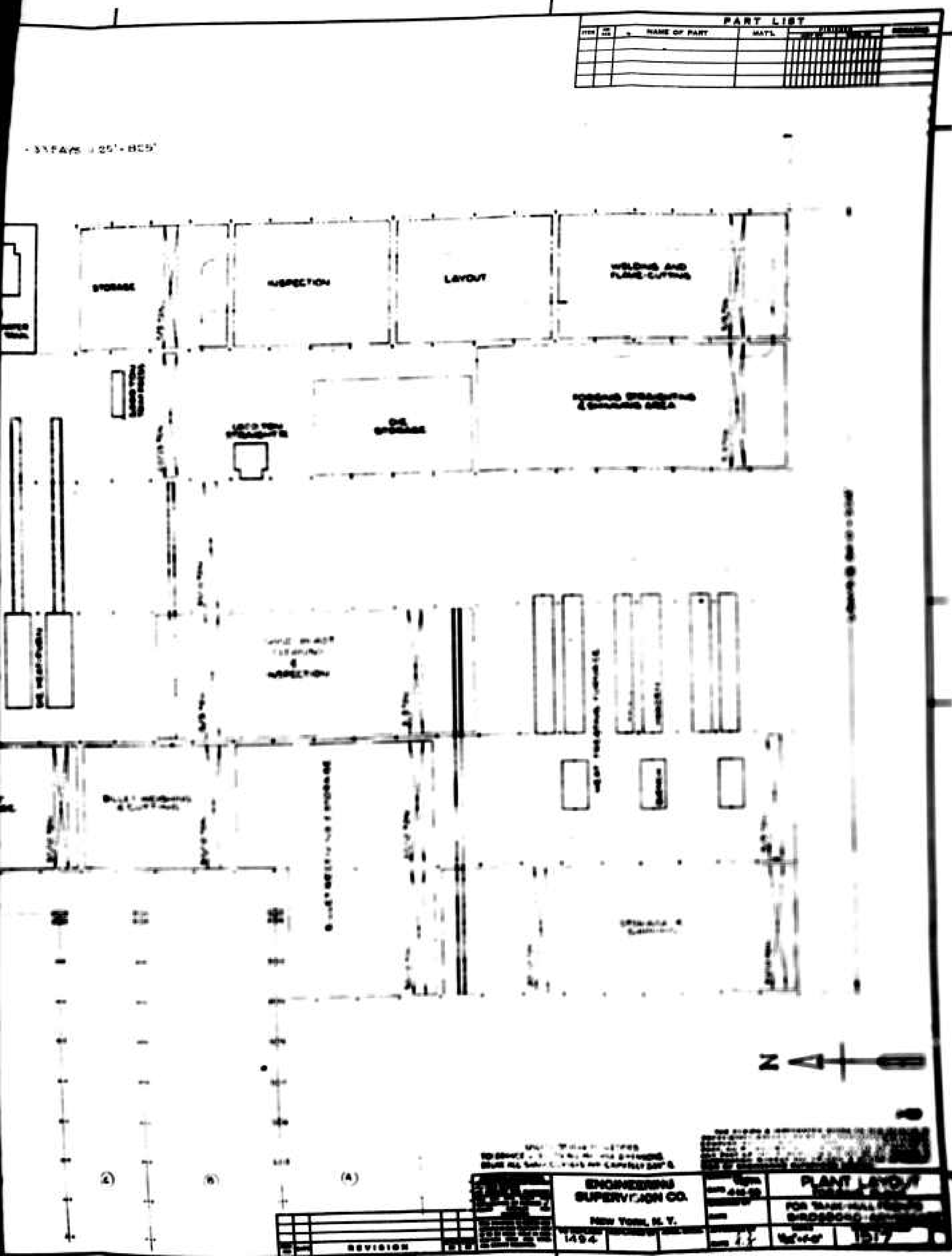

OFFICE AREA
PUMPS & MOTORS
ACCUMULATOR BOTTLES
MAINTENANCE DEPARTMENTS
EXISTING BUILDING
ROTARY FURNACE
BILLET REHEAT FURNACE
BILLET STORAGE
BILLET WEIGHING & CUTTING
BILLET RECEIVING & STORAGE

1


PART LIST
NAME OF PART
MAT'L
REMARKS
STORAGE
INSPECTION
LAYOUT
WELDING AND FLAME-CUTTING
DIE STORAGE
FORGING STRAIGHTENING & GRINDING AREA
SAND BLAST CLEANING & INSPECTION
STORAGE & SHIPPING
HEAT TREATING FURNACES
N
REVISION
UNLESS OTHERWISE NOTED
ENGINEERING SUPERVISION CO.
NEW YORK, N. Y.
PLANT LAYOUT
FORGING PLANT
FOR TANK-HULL FRONTS
WYMAN-GORDON
1455
1500

2


1
OFFICE AREA
PUMPS & MOTORS
ACCUMULATOR BOTTLES
MAINTENANCE DEPARTMENTS
BILLET REHEAT FURNACE
BILLET STORAGE
EXISTING BUILDING


PART LIST
NAME OF PART
MAT'L
STORAGE
INSPECTION
LAYOUT
WELDING AND
FLAME-CUTTING
DIE
STORAGE
FORGING STRAIGHTENING
& CHIPPING AREA
INSPECTION
REVISION
ENGINEERING
SUPERVISION CO.
New York, N. Y.
PLANT LAYOUT
1494
1517

2